MOTION PICTURE PROJECTION

This edition of MOTION PICTURE PROJECTION, SOUND PICTURES, is dedicated to the I. A. T. S. E. & M. P. M. O. of U. S. and CANADA, in grateful appreciation of the support given us by the members over the 30 years this book has been in circulation.

This book was the first book on projection to be endorsed by the I. A. T. S. E. & M. P. M. O. for use by its members. Individual members and officers have over these many years given us wholeheartedly of their cooperation and help in making each succeeding edition of this book more helpful to the craft.

For this cooperation and help we are indeed grateful.

JAMES R. CAMERON

MOTION PICTURE PROJECTION and SOUND PICTURES

BY

JAMES R. CAMERON

Fellow, Society of Motion Picture Engineers. Member, Institute of Radio Engineers, The Acoustical Society of America. Late Technical Editor, Motion Picture News and Projection Engineering.

INTRODUCTION

by

RICHARD F. WALSH

International President

International Alliance of Theatrical Stage Employes and Moving Picture Machine Operators of the United States and Canada.

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30th YEAR

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SERVICING SOUND MOTION PICTURE EQUIPMENT
SOUND PICTURES TROUBLE SHOOTERS MANUAL
QUESTIONS & ANSWERS SOUND MOTION PICTURES
CINEMATOGRAPHY & TALKIES
ENCYCLOPEDIA ON SOUND PICTURES
MOTORS AND MOTOR GENERATORS
ELECTRICITY FOR THE OPERATOR
MOTION PICTURES WITH SOUND
MOTION PICTURE OPTICS
RADIO FOR BEGINNERS
RADIO & TELEVISION
AMATEUR MOVIE CRAFT
TEXT BOOK ON RADIO
TALKING MOVIES

1947

AUTHOR'S FOREWORD

With the publication of this the 10th edition of Motion Picture Projection, the book enters its 30th year of continuous publication. The writer, who started his "operating" days away back in 1903, just seven years after the showing of the first motion picture, celebrates his 43rd year of motion picture activity. The first edition of Motion Picture Projection was a paper covered book of 140 pages, this was published by the American Red Cross during the first world war, for use of the Red. Cross, The Knights of Columbus, The Jewish Welfare League and the Y. M. C. A. It was these four organizations that supplied all entertainment for the United States armed forces, both in this country and abroad for the duration of World War one.

It was early in 1918 that the first edition of this title was published by the American Red Cross, with which organization the writer was connected during the first world war. This was a paper covered book of 140 pages, prepared as a text book and guide for use of the motion picture department of the American Red Cross, the Knights of Columbus, the Jewish Welfare League and the Y. M. C. A., all of whom used the book in their various war activities both here and abroad for the duration of the war.

The demand for the book continued over the years immediately following the end of the war, and a new and larger second edition was published in 1921. This was a book of 350 pages which went into two additional printings.

By 1923 when the third edition was published the book had grown in size to 1,100 pages, this edition carried an introduction by our old friend, the late S. L.

Rothafel (Roxy). A second printing of this edition was found necessary in 1924 and a third in the following year.

The fourth edition of the book published in 1928, made its appearance just as the motion picture screen was learning to talk, this edition, one of 1200 pages, went into three additional printings over the years 1929 to 1931.

With the fifth edition was incorporated the book Sound Pictures, this being published under the joint title of Sound Pictures, Motion Picture Projection. Published in early 1933 this edition carried an introduction by Dr. Alfred N. Goldsmith, President of the Society of Motion Picture Engineers, and Past President of the Institute of Radio Engineers. The book had grown to one of 1550 pages, and much larger in overall size, in fact experience showed us that the book had become too heavy and cumbersome for practical handling, so we decided with the publication of the sixth edition, to divorce as far as possible, all data pertaining to servicing, and installation from actual theory and operating information, and confine ourselves to data of first importance to the projectionist, leaving the subject of servicing for another volume.

The sixth edition in this new form was published in 1936, a second printing of this edition was necessary in 1937, a third and fourth printing in 1938.

The eighth edition of the book, with an introduction by Mr. H. Griffin, Vice President of International Projector Corporation, and President of the Society of Motion Picture Engineers, was published in 1942, and four extra printings of the book were necessary to fill the demands made by U. S. armed forces in the camps in this country and in every theater of operation abroad. It was in early 1944 that the ninth edition was published, and this went into extra printings in 1945.

The entire equipment necessary for starting in the motion picture exhibiting field when the writer first started in the business in 1907, could be obtained at a cost of $78.00. This was the advertised price for a

projector, gas-jet burner, four short film subjects and a phonograph with two records. In 1917 when the first edition of this book was published the cost of the projector and booth equipment had increased to around $500.00. Today the equipment for the projecting of sound motion pictures runs into thousands of dollars.

Today the engineering of such equipment is approaching ever more closely an exact science; the underlying laws are well understood, and the factory processes and the quality and precision of the final product generally leave little to be desired.

It is well that this is the case, for there is probably no other single device in the motion picture field which is so important as the projector and sound mechanism. It is of no avail if a clever and appealing story for the picture is selected; a skilled and imaginative director placed in charge of its production; experienced and inspired actors chosen suitably for the various parts; artistic effort of a high order lavished on the sets and the best possible camera work and sound recording; editing superbly carried out, and the final release print made with the utmost care if, after all this trouble and expense, the print is carelessly run through a poor projector or the sound reproduced by a defective mechanism.

The motion picture projector and sound reproducing equipment form, literally, the "neck of the bottle," and all that precedes them is of no interest to the audience if the result is ruined in this final and crucial stage. So far as the audience is concerned it may even be truthfully said that, given a good story and skilful production and printing of the picture, the projection of the picture *is* the picture.

The picture seen on the screen and heard from the stage is what the audience pays for, and the entire costly structure of the producing industry must perforce rest on this foundation. The box office is the audience response to the final screen picture and sound, and it is therefore eminently fitting and necessary that no stone be left unturned to produce the best theater equipment of this type possible for modern engineering and

to handle it by as skilled, earnest and informed projectionists as can be secured.

Projectionists should therefore be craftsmen of a high order since they are in a key position to make or mar the audience response to all that has been done before the print reaches them. They are members of a respected and skilled profession, the level of which they can raise to almost any plane they may desire by securing and utilizing the special knowledge of projection problems which they should have.

The introduction of sound equipment into the projection rooms has added greatly to the projectionists duties, the multiplicity of reels necessary for the presentation of a complete program, and the fact that four, five or six complete programs must be run off to constitute a day's work, the care and operation of the sound equipment in addition to that of the projectors and accessories, the necessity for the projectionists to at all times remember that they are handling a Cellulose-Nitrate-Camphor Film, which is in turn run through projectors equipped with an arc-lamp giving off heat at the crater spot of more than 3,700 degrees Centigrade, means to-day that a man must be stationed at each motion picture projector, this is not only necessary due to the ever present fire risk, but it is essential to obtain maximum screen results, and after all is said and done, maximum screen results is what the exhibitor is selling the box office patron.

It is necessary for projectionists to have at least a working knowledge of more than half a dozen subjects,—he must be an electrician, or at least thoroughly understand the application of electricity to an arc-lamp, he must understand the construction, operation and care of motors, motor-generators and other electrical equipment used in his daily work, he must understand electrical wiring,—he must know something of optics, the nature of light, lenses, condensers and reflectors—he must be a mechanic, to understand the working principle of the projector and its various parts, and he must be able to make minor repairs and adjustments—he must know something about photography, his work

consists of projecting a series of photographic images onto the screen—he must have a good working knowledge of radio and sound transmission—and he should know something of acoustics.

The proper installation, suitable maintenance, and skilful handling of projection equipment should greatly interest the exibitor and producer alike—for it represents artistic triumph, public satisfaction, and dollars in the pockets of both. Bright lights on the marquee and dim pictures on the screen form an extremely poor combination.

In the preparation of this book down through these years, we have always had the wholehearted cooperation of the entire motion picture industry. Practically all of the larger industrial concerns have placed the results of their research laboratories at our service, thus materially helping us with each succeeding edition. To these concerns we wish to express our thanks and sincere appreciation:.

We wish to thank the officers and members of the International Alliance of Theatrical and Stage Employees, Moving Picture Operators of the United States and Canada for their loyal support of our work, and for the many complimentary things they have written in praise of our books. It has always been a source of satisfaction to know that our Motion Picture Projection was the first book on the subject to be endorsed by the I. A. T. S. E. & M. P. M. O.

We wish too, to express our appreciation for the endorsement of our books given by the American Radio Servicemens League, and the British Guild of Motion Picture Projectionists in London, Eng.

We appreciate too and herewith give full acknowledgement for the valued help extended us by our brother members of the S. M. P. E. ever since this organization was founded away back in 1918, and to the Motion Picture Academy of Arts and Sciences.

Through the medium of our books we have made many, many friends, not only in this country but throughout the entire English speaking world. We would like the many hundreds who have written us,

to know that we are indeed grateful for the sentiment contained in these letters.

We are always pleased to hear from our readers, we invite and appreciate criticism of our work, for in this way, we hope to improve each succeeding edition.

In presenting this the new eighth edition of Motion Picture Projection, may we express our thanks and appreciation to the thousands of readers of our earlier editions, to the various United States and Canadian Government departments, to the great number of libraries, and educational institutions who have adopted the books, to the Trade and Lay press throughout the world who printed such complimentary things about our efforts, and we sincerely hope that this new edition will meet with the approval of all, in and outside of the motion picture business.

James R. Cameron
Coral Gables, Florida, U. S. A.

INTRODUCTION

To those of us who have daily personal contact in the motion picture industry, there is great satisfaction when we visualize the tremendous strides that have been made in the development of projection room practices and equipment. These developments are of signal importance to the millions of patrons of the justly popular motion picture entertainment, and have given a new impetus to one of America's greatest industries.

The vast patronage with which the motion picture theaters have been favored is the greatest assurance that these technical and mechanical developments have found instant public favor, and that future developments of similar character will be received with like satisfaction by the general theater going public.

The worlds greatest research laboratories, presided over by the outstanding scientific and mechanical geniuses of our times, are at this present moment bending every effort toward the development and perfection of new mechanical devices for introduction into the theater projection rooms of this country. The new scientific discoveries of the recent world war are already being used in numerous ways in this new type equipment, and it is only a question of time before this new equipment will be introduced into the theaters of this country. Another possibility is third dimension projection. The mechanical development of new projection equipment and projection room practices is unquestionably destined to play a great part in the future progress of the motion picture industry.

With the coming of these vast changes in projection room practices, the members of the projectionists local unions throughout the United States and Canada are fully alive to the great responsibilities that

will devolve upon them and are preparing themselves by intensive study and training, to meet the changed and changing conditions that will be forever present. It may not be generally known to the public, that many of the larger I. A. T. S. E. unions have arrangements whereby their individual members are now given regular courses in subjects allied to sound projection, to prepare them for these changing conditions. I. A. members, no matter where located, knowing of these new mechanical developments are leaving no stone unturned to see that they will be fully capable of manning this new type of equipment in an expert manner.

The theater going public, to whom the motion picture theater has come to be an indispensable necessity, and those who have hundreds of million of dollars invested in this industry, need have no concern regarding the ability of the projectionist to cope with any new projection room problems. New projection room equipment, no matter how complicated or revolutionary it may be, is always a welcome addition to the projection room. The projectionist of today is more of an idealist than a working man. He looks upon motion picture projection as an Art, and is ever striving to improve the quality of screen entertainment even though it entails a personal sacrifice.

The consciousness that the success or failure of the entire screen performance is dependent upon his skill and its application in the handling of the intricate projection and sound reproducing equipment, has a natural tendency to keenly arouse him to sense the great responsibility of his profession. He approaches his task, not from the standpoint of a worker who is to receive a monetary consideration in the form of wages for a given number of hours of service, but rather from the standpoint of an artist, mechanically etching upon the silver screen a series of beautiful photographic images that are unfolding to his movie audience a visual impression of a story told with the aid of his mechanical pen. And at the same time he deftly manipulates the projection sound equipment so as to give proper modulation and effect to the spoken

word or the music run in synchronism with the photographic images, so that the illusion of actually giving life and voice to the story book characters may be complete.

The projectionists who pioneered the introduction of sound have every right to feel a great satisfaction in the contribution they have made in the development of this epochal achievement. The problems met with, and overcome by the projectionists in the early days of sound proved to the entire industry the progressiveness of the projectionist of today. These men are deserving of the highest commendation from the entire motion picture industry for this splendid technical service.

The theater audience cannot be expected to appreciate the painstaking efforts incorporated into the work of the projectionist in attempting to present for their enjoyment a faultless screen performance. How are the members of the audience to know of the projection problems that are to be overcome in producing the screen results which they expect and demand? They have no means of knowing the constant care and attention necessary on the part of the projectionist in caring for his equipment so there will be no interruption in the performance. A proper appreciation of the work of the projectionist by the theater patron, and by others who should be better informed, will not be forthcoming until we have succeeded in dispelling the popular misconception that the duties of the projection room staff are to operate and care for electrical and mechanical equipment and devices which are automatic in operation and require but scant personal attention.

No attempt will be made here to stress the mechanical ability of the capable projectionist, nor shall we dwell upon the requisite understanding of electrical phenomena which is indispensable to the solution of projection room problems. Of the projectionist's familiarity with the principles of optics, we shall only say that without this knowledge the splendid image definition which is characteristic of the projected screen picture would be impossible of attainment and

the beautiful photographic results of the consumate skill of the cameraman would be wasted.

It is true of course that an able projectionist must be a good mechanic, but it does not naturally follow that a good mechanic would be an able projectionist. Our impression is that real showmanship is one of the most essential qualities for the real projectionist. He must be show-minded in all the term implies, with a background of theatrical experience which will inbue him with that inherent theatrical spirit "The show must go on" no matter what happens. No amount of academic training could possibly produce an outstanding projectionist. The essentials for good projection are not to be learned out of books alone, but good books are of invaluable aid to both novice and experienced projectionist, no man ever lived who knew as much as he ought to know. When any man reaches a point where he imagines he has all the knowledge he should have, it is a certain indication of his need of it.

It is a pleasure to note that the better class of theaters have at last come to a realization of the importance of the projection room and are now willingly furnishing adequate and modern projectors and equipment, which enables the projectionist to produce the proper screen results. Good projection calls for the use of good projection equipment, the use of inadequate and antiquated equipment invites not only trouble in the projection room but also trouble at the box office. Bad projection and good business are never companions.

A proper understanding of projection, and this calls for more than just knowing how to operate the equipment, will add immeasurably to one's value to the industry. We want to caution all projectionists against ever being satisfied with projection mediocrity. There is always room for improvement, no matter what has already been accomplished. Perfection in projection has not been achieved, irrespective of the splendid progress made over the past few years. Let all of us who are interested in the advancement of the science of motion picture projection rededicate our purposes

to the continuance of the struggle for better projection, a struggle not rooted in selfishness; an effort not in the interest of personal gain, but a contribution to the motion picture industry through cooperation and good will. Let us spare no effort to enchance the value. of the motion picture as an art by earnestly and constantly striving for greater appreciation of motion picture entertainment through the application of the scientific principles and practices which produce the highest standards of motion picture projection.

In closing we would here like to pay tribute to all those who have in the past worked with the projectionist in helping him gain wider knowledge of the various technical subjects necessary to his work. We appreciate the work done by the various technical societies and trade magazines, and it seems fitting to pay a special tribute to the Cameron Publishing Company, publishers of the Cameron handbooks, who are now celebrating their 30th year of publishing books for projectionists, for their cooperation with the members of our craft, down through these many, many years.

RICHARD F. WALSH

International President

International Alliance of Theatrical Stage Employes
and Moving Picture Machine Operators of the
United States and Canada.

ACKNOWLEDGMENT IS HEREBY GIVEN TO:

International Projector Corporation, National Carbon Company, Ampro Corporation, General Electric Company, Academy of Motion Picture Arts & Sciences, Jenkins Radio Company, Joseph A. Dubray, Bell & Howell Company, Eastern Kodak Company, Western Electric Company, Motiograph Company, S. M. P. E., DeVry Corporation, Herbert Griffin, Nat Golden of the U. S. Department of Commerce, William Kunzmann, Karl Brenkert, Harry Strong, Strong Electric Corporation, A. J. Lindsley, National Theater Supply Corp., W. F. Scranton, RCA Corporation, J. E. McAuley, Communications, Joe Cifre, D. C. Galliard, Erpi, H. G. MăcPherson, RCA Review, International Projectionist, S. O. S. Cinema Supply Co., Westinghouse Manufacturing Co. and all others who in any way helped us in the production of this book.

MOTION PICTURE PROJECTION

Every great invention is, of course, closely related to theories and to actual results expounded and obtained by a number of researchers previous to the invention itself.

Motion pictures do not deviate from this rule and have so evolved from a series of discoveries in all of the branches of the physical, chemical and mechanical sciences.

It appears quite well corroborated that Jules Duboscq, in Paris, in the year 1851, was the first to apply photographic images to the demonstration of the persistence of vision. He constructed for this purpose an apparatus which he called the *Bioscope.*

In 1854 Beale, of Greenwich, England, photographed movement analytically and *projected* it. From 1860 there has been almost a deluge of different methods of solving the problem, more or less practical devised either for amusement or for scientific research, but all of them tending to the ultimate result of obtaining both the *analysis* and the *synthesis* of movement—Du Mont; Ducos de Houron who was, in 1864, granted the first patents mentioning the application of photography to the analysis of movement; Seller, of Philadelphia; Lincoln, of Providence, R. I.; Huyl, of Philadelphia; Janssen; Donisthorpe, in London; Le Roy, in New York City; Anschutz, in Germany; Le Prince, Jenkins and many, many others, among whom the outstanding figures are unquestionably, Muybridge, of California; Friese-Greene, of London; Lumiere, of France and Thomas A. Edison of the United States.

Motion Picture Pioneering

In the year 1872, Edward J. Muybridge began his experiments in analytic photography to establish the phases of movement of animals at different gaits.

The First Animated Photographs.
Projected by Henry Heyl before 1500 people, in Philadelphia, 1870.

His method involved the use of batteries of cameras and the pictures were obtained from three different angles simultaneously. The cameras were usually aligned by batteries of 12 or 24, one of the improvements he applied to them being the use of only one camera with a battery of lenses.

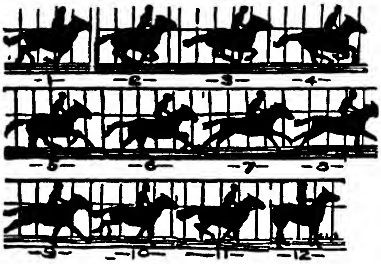
The action of the shutter corresponding to each lens was electro magnetically controlled so that the shutter would function when the subject was in front of the camera.

His strip pictures, then, analyzed the movement, keeping the subject in the center of each plate for the cameras set perpendicular to the direction, while the other cameras photographed the approach or going away of the subject itself.

In 1882 his work made quite a sensation throughout the world, when he presented his pictures printed on a disc *"by the aid of an astonishing apparatus called a zooproxiscope which the lecturer described as an improvement on the old zoothrope,"* as it is related in the transactions of the Royal Institution of Great Britain pertaining to such demonstration *by projection;* presented by Muybridge on the 13th of March, 1882.

The United States Government granted Muybridge patents on his process in the years 1879 and 1883.

Although Muybridge's process, as can easily be understood, was exceedingly crude and cumbersome in its workings, it proved to the world the possibilities of photography being applied to the reproduction of movement. Muybridge's first experiments were carried out with the collodion process and later he applied more modern methods such as rapid sensitized papers, but there is no evidence of his experimenting with the gelatino-bromide process with which he was undoubtedly acquainted.



Muybridge's Running Horse

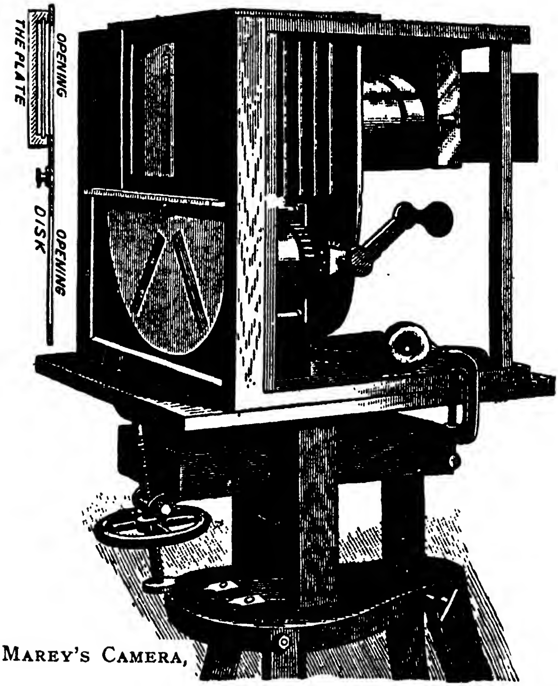
Marey's Photographic Gun

Dr. E. J. Marey, of Paris, perfected, in 1882, a photographic gun, described under another form by the French savant, Janssen and used by the latter in astronomical investigations.

Doctor Marey made extensive use of his gun for the photographic analysis of the flight of birds. The instrument had the shape of a gun, hence its name, the lens hidden in the barrel and the photographic plate in the cyclinder. By pressing the trigger of the gun the plate would revolve and 12 pictures were taken on it through proper intermittance of movement and occultation during the revolving of the plate. Doctor Marey was the first to obtain analytic pictures in rapid succession by means of a single lens. The number of pictures taken with the gun, though the instrument was so perfected

that it was possible to effectuate the change of the plate without any appreciable loss of time, was very limited.

Doctor Marey later constructed a camera, and was able to present at the exposition of Paris in 1889, motion pictures of street scenes, obtained by the use of film pulled and held in position by a system of cams and gripping plates.



Marey's Camera,

Georges Demeney, a collaborator of Doctor Marey, brought about several improvements on the latter's apparatus especially an ingenious device for the intermittent progression of film in the camera.

The application of original ideas in the apparatus warranted the granting to him of patents in 1893. The construction of the apparatus was conducted by Gaumont who became in time, one of the most important manufacturers of motion picture apparatus and also a producer of motion picture films.

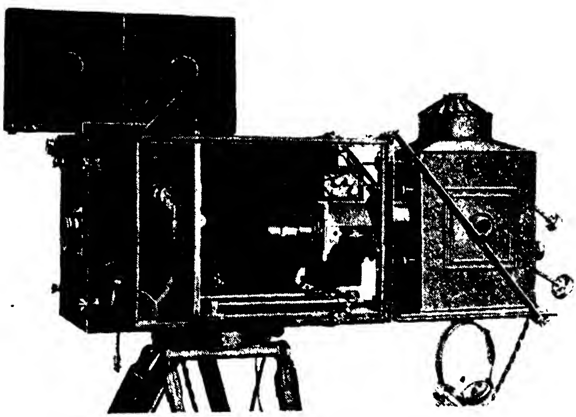
CELLULOID

A material similar to *celluloid* was first made in England by Alexander Parkers, in 1855, under the name of *Parkesine*. It was for several years made only in bulk for the manufacture of several objects of common use. In 1869 the brothers Hyatt, of Newark, N. J., invented celluloid as it is known today, a clear transparent material obtainable with great uniformity and possible to be manufactured in thin sheets of even thickness.

The replacement of glass as a support for the sensitive emulsion had been considered by several, and the research conducted on this matter included the coating of transparent paper, of sheets of gelatine rendered insoluble and thus hardened, until in 1887 the use of celluloid was permanently established as an ideal support due to its clearness and flexibility.

Through this innovation it was then possible to prepare bands of sensitive material and it was clear that such bands could be made of almost unlimited length through appropriate mechanical processes.

The use of celluloid for this purpose can be traced back as

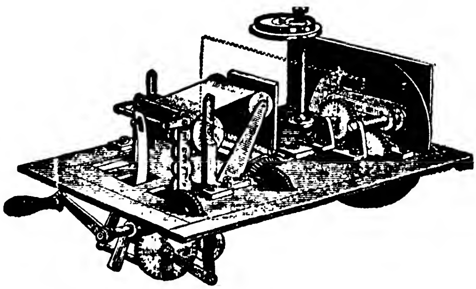


Lauste's combined camera for sound and scene

far as 1881, but its use became stabilized in 1887 at which date Rev. Hannibal Goodwin applied for a patent on a process for

coating celluloid ribbons with sensitive emulsions. Graff and Jougla founded the same year a factory for the manufacture of rolls of film in Paris, the first to be established in Europe, and soon after Blair and the Eastman Kodak Company entered the field.

The discovery of celluloid and its application to photographic processes simplified considerably the problems of movement reproduction, which were reduced by this time to purely mechanical ones, such as the discovery of the most appropriate means for imparting to the film the proper intermittent movement in the camera as well as in the projecting apparatus, and the proper phases of exposure to, and occultation from the light most in accordance with the phenomenon of persistence of vision.



Friese-Greene (1888) camera

Celluloid Films and Motion Pictures

William Friese-Greene, as early as 1885, had produced analytic and synthetic pictures on glass plates and, in 1889, applied for patents for a practical camera using film bands. Friese-Greene and his collaborator Mortimer Evans, were granted patents on June 21, 1889, on a camera constructed to "*produce a series of instantaneous photographs of moving bodies which may afterwards be combined to produce animated pictures.*"

The intermittent movement of the film was secured through a series of rollers and gears and a spring for the release of the

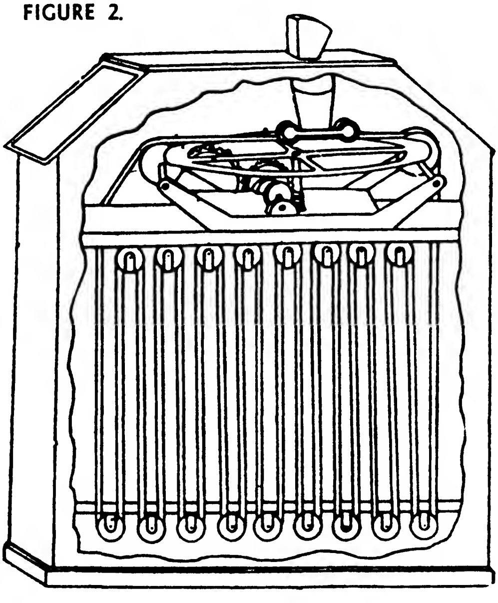
film after exposure.

The shutter consisted of two oscillating blades, one pierced with an aperture permitting the exposure of the image and the other acting merely as a light screen.

The time of exposure was regulated by means of a tension spring connected with the shutter.

This instrument doesn't seem to have ever been put into real practical use, although its principle and workings and ingenuity of construction entitle Friese-Greene to the recognition

FIGURE 2.



THE EDISON KINETOSCOPE

of his efforts as a pioneer in the development of motion pictures.

Thomas A. Edison, the great American inventor, and his collaborators conducted a practical investigation on the subject, which led to his filing application for patents, August 24, 1891, on both a camera, the *Kinetograph*, for taking analytic pictures of movement, and an apparatus for viewing them synthetically, the *Kinetoscope*.

The camera as described in the patent consisted of *"an apparatus for effecting by photography a representation suitable for reproduction of a scene including a moving object or objects comprising a means for intermittently projecting at such rapid rate as to result in persistence of vision images of successive positions of the object or objects in motion as observed from a fixed and single point of view, a sensitized tape of film and a means for so moving the film as to cause the successive images to be received thereon separately and in a single line therein."* The patent specifications contained also the description of an *"intermittent motion for exposing successive portions of the film during the periods of rest"* and of *"an unbroken transparent or translucent tape-like photographic film provided with perforated edges and having thereon equidistant photographs of successive positions of an object in motion, all taken from the same point of view."*

The viewing apparatus he described as consisting of *"a series of rollers, a tape on which are a large number of pictures of a moving object passed back and forth over said rolls by suitable means whereby the tape may be fed forward, a light for illuminating said pictures as they pass over it, a sight opening and prisms for directing the beams to said sight opening"* and provided with a system for cooling the light and *"a shutter having an opening in it for exposing the pictures one after the other."*

The Kinetograph was so designed and constructed that 46 pictures were taken per second. The shape of the picture being round all the pictures were placed horizontally along the film instead of vertically one on top of the other, as they are today. The negative obtained was *printed* on another strip of film by means of an apparatus called a *reproducer* and finally viewed in the Kinetoscope which as the patent specification explains was a peep-box which could be used by only one person at the time. It was not until December, 1895, that Edison consented to consider a projector invented by Armat which was in turn soon supplanted by the Biograph projector.

It is quite interesting to note that Edison's greatest preoccupation seems to have been the discovery of a system by

which motion pictures could be synchronized with sound. Mr. Laurie Dickson relates that as early as 1887, he started in collaboration with Edison an investigation on the possibilities of such adaptation which brought to light the *Phonokinetograph,* an apparatus combining a photographic camera and a phonographic recorder.

Edison's Kinetoscope was soon known throughout the world and when exhibited in Paris, it spurred Mr. Louis Lumiere on to new researches for the perfection of the projection of the analytic pictures in which he had interested himself by following the work of Marey and Demeney, which researches resulted in his constructing an apparatus in which sensitive strips of paper were used. Louis Lumiere and his brother Auguste were engaged in the preparation of sensitive photographic emulsions which were reputed throughout the world. The "Lumiere et ses Fils" Company, of Lyon, enjoyed and still enjoys a very enviable reputation as producers of medical products, photographic chemical products, sensitive papers, plates and films. The Lumiere brothers soon discarded the paper negatives and proceeded to coat celluloid in their own factory.

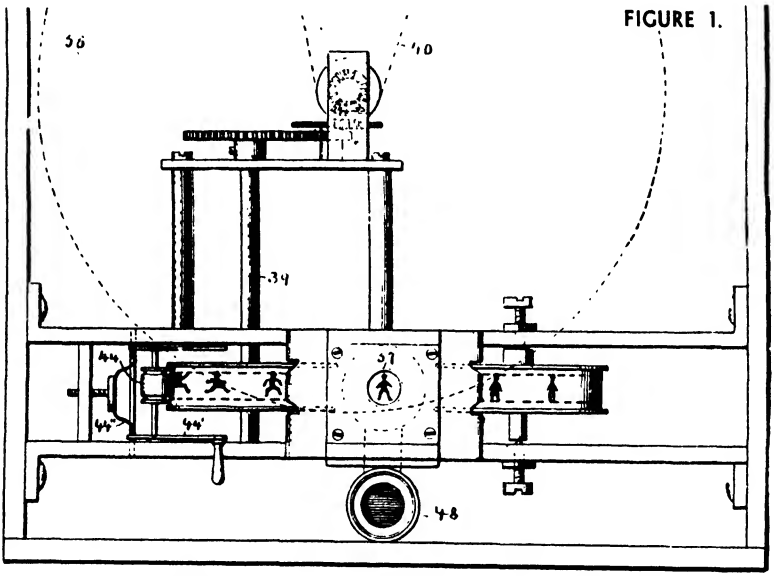
From their experiments and diligence resulted an apparatus which they called the "*Cinematographe,*" designed and constructed to serve for both the taking of pictures analytic of movement and the projecting of their positive prints on a screen, at the rate of 900 images per minute. The initial strips of film were of a length of 50 feet and 35 millimeters wide, the images themselves measuring 25 by 20 millimeters each.

The film was perforated on both edges by circular holes in which the pins of the driving mechanism would engage.

Patents were granted them the 13th of February, 1895, on "*an apparatus which can be used for obtaining and viewing chrono-photographic images in which a ribbon destined to receive or having received the successive images is animated by intermittent movements, separated by intervals of rest, by means of pins entering on regularly spaced perforations on the edges of the ribbon. Said ribbon receiving or showing the successive images through an aperture alternatively masked*

and unmasked by a disc serving as shutter, the unmasking of the image corresponding to the periods of rest of the ribbon.

"A mechanism composed of a shaft holding the shutter disc an eccentric cam and handle serving to give the pins a forward and backward movement and the cam serving to give an upward movement to the same pins for such length as to correspond with the intervals of rest of the ribbon."



Drawing Accompanying the Edison Patent Application

Edison's Application For Patent Covering Apparatus For Exibiting Photographs of Moving Objects (1891)

"The present invention relates to apparatus for using photographs which have been taken in rapid succession of an object in motion, by means of which a single composite picture is seen by the eye, said picture giving the impression that the object photographed is in actual and natural motion.

"The object of the invention is to provide an efficient apparatus adapted to pass a large number of pictures rapidly before the eye of the beholder in regular order, and the inven-

tion consists in the several combinations forming the apparatus, or definite parts thereof, hereinafter fully described, and set forth in the claims.

"In the accompanying drawings, Fig. 1 is a plan view of the reproducing apparatus, the top of the inclosing case being removed. Fig. 2 is a rear view of the apparatus, the back of the case and the motor being removed and the frame being broken away to show some of the parts behind it. Fig. 3 is a sectional view showing the arrangement of reflector, light, film, &c. Fig. 4 is a view illustrating the reproduction of stereoscopic pictures; and Fig. 5 shows a modified form of lens and shutter.

"The film 3, on which a large number of photographs of a moving object have been taken in such manner that any two successive pictures are almost identical in appearance as set forth in my application, Serial No. 403, 534, filed August 24, 1891, is passed back and forth over rollers 36, 37 at the top and bottom of the inclosing case respectively, the ends of the film being connected so that the film forms an endless band or belt. This band is advanced at the proper rapid speed by the reel 38 on the shaft 39 driven through the belt 40 by any suitable motor. The film passes over the pulley 41, under the light spring 42, through the slit 43, and over the reel 38. In order to get a sufficiently long strip or tape—say several hundreds or thousands of feet—the rollers 36, 37 may be multiplied to any desired extent.

"44 is a brake-roller, carried by the crank-arm 44′, provided with a suitable handle and thrown forward by a spring 44″.

"Below the passage through which the film is led is a glass cell 45 containing alum water for the purpose of absorbing heat-rays from the electric or other light 46. This is shown as an incandescent lamp, which, when the apparatus is in use, is continuously lighted, but it is only essential that the light should exist when an opening in the shutter comes over a picture. The cell 45 has a branch 47 terminating in a reservoir or tank 48, which is tightly closed by a rubber diaphragm 49 held in place by the clamping ring 50. On the surface of

the alum water is a surface 51 of oil to still further prevent evaporation. Above the cell 45 is a ground-glass plate 52 for still further absorbing the heat-rays and protecting the film. This plate may be tinted to give the picture the appearance of a colored picture, the plate being all of one tint, or partially of one tint and partially of another tint, according to the subject and arrangement of the picture. Above the film are suitable lenses or prisms 53, and a sight opening 54 through which an observer can look to see the reproduced picture.

"55 is a reflector below the lamp to throw the light upward to the film.

"In the reproducing apparatus a shutter is used for covering and exposing the pictures successively in much the same manner as the sensitive film is exposed in taking the photographs. The position of such a shutter is indicated in dotted lines at 56, Fig. 1. This shutter has one or more openings 57 near its edge, the single opening shown being directly over one of the pictures on the film. This shutter is continuously revolved through the belt 40 with a speed sufficient to bring the opening centrally over a picture at intervals practically equal to the intervals between exposures in taking the pictures. The means for advancing the film and for operating the shutter to expose the pictures may be the same in all particulars as in the apparatus for taking pictures described in my application, Serial No. 403,535, filed August 24, 1891. When the brake 44 is released by means of the handle, the film is pulled forward between the lamp and the prisms at a regulated speed, corresponding to the speed at which the pictures were taken, when the observer at the sight opening will seem to see a single picture, the object represented being in easy and natural motion, owing to the fact that the successive pictures are so nearly alike that at a glance they cannot be clearly distinguished from each other, although they do in fact represent positions of the object at different moments.

"I propose in some cases to use a film on which pictures have been taken stereoscopically, that is, in which pictures have been taken in pairs side by side on the film, as fully described in my application, Serial No. 403,535. This ar-

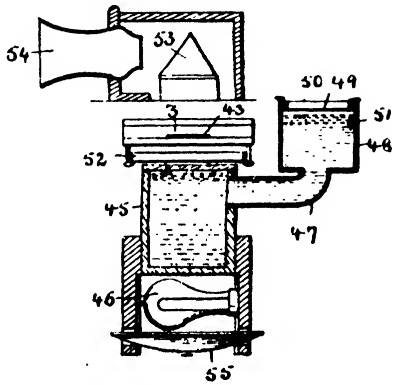
rangement is indicated in Fig. 4, in which 3 is the film, which is supposed to be movable in a line at right-angles to the paper. On the film at regular intervals are the pictures arranged in pairs. These pictures are indicated by the two heavy lines 3′.

"46 is the electric lamp.

55 is a parabolic reflector, and 45 the alum cell between the lamp and the film.

45′ are prisms for deflecting the rays from the two pictures and superposing them on the projecting lens 45″. 56 is the

FIGURE 3.



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shutter, which is rotated at a constant speed and which is provided with an opening 57 adapted to uncover the lens at regular intervals.

57′ is a screen on which the picture is projected. This screen may be white or, preferably, may be colored to give the picture the appearance of a colored picture; for example, if the picture shows sky and earth, the upper part of the screen may be colored blue and the lower part brown, and it may be otherwise colored for other objects. The reproduction of stereoscopic photographs of moving objects gives a very vivid impression of movement, and the coloring just described adds to the realistic effect.

"Instead of using a large shutter such as above described, I may use a very small shutter with a small opening by placing it near the center of the lens through which the rays pass,

the shutter being placed in a slit in the body of the lens, and the opening in the shutter passing across the line where the converging rays intersect. 58 indicates a lens, 59 a slit therein, 60 a small shutter adapted to rotate in the slit, 61 an opening in the shutter, 62 the light-rays which intersect and pass through the opening 61.

"I am aware that a heat absorbent, such alum water, has been used in connection with microscopes between the objects being examined and the lens to protect said object from the effect of heat concentrated thereon by said lens. I do not, therefore, claim broadly the use of such heat absorbent, but only the use thereof in combination with the moving film having pictures thereon and certain elements of my apparatus, as hereinafter defined in the claims.

"What I claim is—

1. The combination, in a picture exhibiting apparatus, of a series of rollers, a tape in the form of an endless belt on which are a large number of pictures of a moving object, said tape being passed back and forth over said rollers, suitable means whereby the tape may be fed forward, and a light for illuminating said pictures as they pass over it, substantially as described.

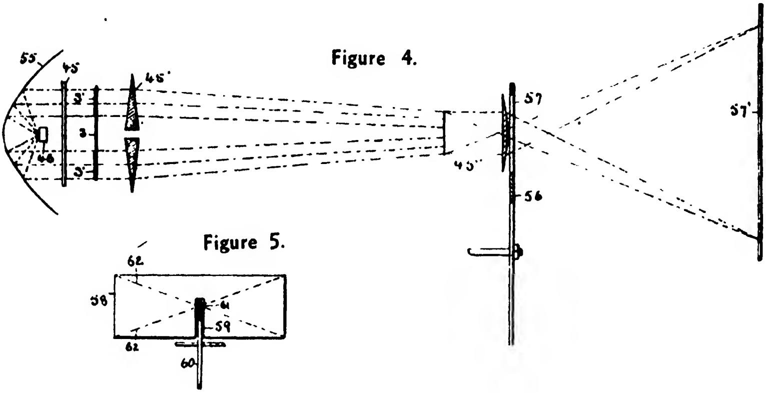
"2. The combination, in a picture exhibiting apparatus, of a series of rollers, a tape on which are a large number of pictures of a moving object passed back and forth over said rolls, suitable means whereby the tape may be fed forward, a light for illuminating said pictures as they pass over it, a sight opening, and prisms for directing the beams to said sight opening, substantially as described.

"3. The combination, in a picture exhibiting apparatus, of a film in the form of a tape and having a large number of pictures on it representing an object in motion, means of supporting and moving said film, a light for illuminating each picture as it passes before the eye, and a transparent heat absorbent between the light and the film, substantially as described.

"4. The combination, in a picture exhibiting apparatus, of a film in the form of a tape and having a large number of

pictures on it representing an object in motion, means for supporting and moving said film, a light for illuminating each picture as it passes before the eye, and a glass cell containing alum water between the light and the film, substantially as described.

"5. The combination, in a picture exhibiting apparatus, of



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a film or surface having a large number of pictures on it representing an object in motion, means of supporting and moving said film, a light for illuminating each picture as it passes before the eye, and a ground glass plate between the light and the film, substantially as described.

"6. The combination, in a picture exhibiting apparatus, of a long endless tape on which are a large number of pictures of an object in motion, a support for said tape, means for advancing the tape, and a shutter having an opening in it for exposing the pictures one after another, said shutter being driven so that an opening comes directly over the film at the same moment that a picture is moved along into position to be seen, substantially as described.

"7. The combination of an endless tape with pictures representing an object in motion and being so nearly alike as not to be readily distinguishable arranged at regular intervals thereon, means for supporting said tape and for moving it

along at a regulated speed, and a light for illuminating each picture as it comes into position to be seen, substantially as described."

Additions to the patents for improvements rapidly followed, March 30, 1895; May 6, 1895; March 28. 1895; November 28, 1896.

Projection room (about 1894), showing phonograph attached to kinetoscope for synchronization of sound and picture. *(Century Magazine,* **18**, 207, 1894.)

ELEMENTARY TALKING MACHINES

No one knows when man first began to speculate as to the possibility of making machines that would talk. It must have been in times when ideas regarding sound and voice were so crude that one imagined the possibility of burying the voice, as in the legend of Midas's barber; and when philosophers were so much in the dark concerning these things that any step they might have taken would have been, without doubt, a wrong one.

It is not our intention here to trouble the reader with an account of the organs by means of which we speak—the cartilages, ligaments, and muscles with hard names that originate and modify the sound of the human voice. But, in passing, we may remark that an ordinary cotton spool, with a couple of stretched india-rubber bands over one end, is a rough representation of one portion of the human apparatus. The tube within the bobbin represents the wind-pipe, and the stretched india-rubber bands over the end of it stand for the vocal cords; and just as one, by blowing down such a spool, produces a musical sound, so a human individual, by sending a supply of air up his wind-pipe from the lungs, and bringing his vocal cords to the requisite tension and nearness, originates a musical sound. This sound is now modified by the throat, tongue, and lips, to produce speech. Hence, if one were to mount over the india-rubber bands of our spool a cavity with artificial lips and tongue, we should have produced a very simple kind of speaking machine, by means of which two or three words might be distinctly articulated.

Upon an analysis of the sounds that are used in speech, it is found that the vast variety of words which make up a language are formed from the combination of a few elementary sounds; just as the untold number of chemical compounds in nature are formed from the union of a comparatively few elements. If there were a proper correspondence between our written and our spoken language, each of these elementary sounds would be represented only by one character. There is, however, a want of correspondence between the characters of our written language and the sounds of our spoken language, which, as Sir Charles Wheatstone has remarked, has been a great obstacle to the proper understanding of the real elements of speech. To quote the same authority: "A child is taught that the letters W, H, Y make the syllable 'why'; now, if we examine the sound of this word, we shall find it to be formed by the rapid succession of the vowel sounds U, *ah,* E. In attempting, therefore, to imitate by artificial means the sound of this word, we should pay no regard to the letters of which it is formed; the elementary sounds alone are the objects of our attention. The same observation is generally applicable to the words of our language." Hence, to make a speaking machine, it had first to be ascertained how to produce each of the elementary sounds; then, by a number of keys like those of a piano, they purposed combining these elementary sounds to form words, as notes in music are combined to form chords.

With a wise perception, the Imperial Academy of St. Petersburg accordingly offered a prize in 1779 for an investigation touching the nature of the vowel sounds—*i.e.,* the five elementary sounds expressed by the letters *a, e, i, o, u,* which are formed out of the sound produced by a continuous expiration, the mouth being kept open, but having the form of its aperture changed for each vowel. The questions the Academy proposed were these:—

1. What is the nature and character of the sounds of the vowels A, E, I, O, U, so different from each other?

2. Can an instrument be constructed, like the *vox humana* pipes of the organ, which shall accurately express the sounds of the vowels?

The prize was won by Professor Kratzenstein, who, after examining the positions of the various organs, and measuring the apertures of the lips, teeth, and other parts, constructed a series of tubes, shown in section in FIGURE 6. which distinctly pronounced the vowels A, E, O, U when their lower ends were blown into through a reed. To produce I, it was merely necessary to blow into the pipe, *a b*, of the I tube. Just half a century after, however, Professor Willis, of Cambridge, in

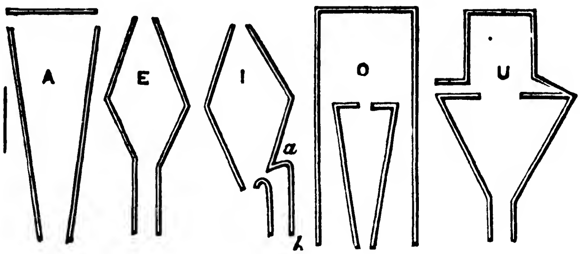


FIG. 6. Kratzenstein's Vowel Tubes

repeating Kempelen's experiments, presently to be described, arrived finally at the conclusion that the forms of Kratzenstein's vowel tubes were quite arbitrary, as he obtained all the vowel sounds from tubes of exactly the same form by simply altering their dimensions. To commence with, Willis found that by employing a shallower cavity than Kempelen had used, he could obtain the vowels without inserting his hand.

It often happens that nearly the same discovery or invention is made by persons living widely apart, and without any knowledge of each other's proceedings; and it appears, in the case under consideration, that while Kratzenstein was thinking and working over the problems proposed by the Imperial Academy of St. Petersburg, there were Von Kempelen, of Vienna, engaged in a more extensive investigation of the subject, and in France the Abbé Mical making large speaking heads.

Mical is said to have never published any details of the speaking heads which he exhibited before the French Academy

in July, 1783. From the accounts of contemporaries who saw them they would appear to have been masterpieces of ingenuity. The heads covered a hollow box, the different parts of which were connected together by hinges. In the interior were artificial glottises of different forms over stretched membranes and, according to Vicq D'Azyr, the air passing through these glottises was directed on to the membranes, and from the combination of the sounds produced there was thus obtained a somewhat imperfect imitation of the human voice. A key-board was attached to one of the heads, which a person properly initiated could finger in order to make the head speak. So far as the poor abbé was concerned, the heads appear to have been a source of anything but satisfaction, as he is said to have smashed them up on being disappointed of the reward which, on the recommendation of the Academy, he had expected from the Government, and shortly after his disappointment he died.

Perhaps the most recent attempt at making a speaking machine of this order is that of Faber, of Vienna. As big as a parlor organ, it has a vibrating reed of variable pitch for its vocal cords; an oral cavity, whose form and dimensions can be quickly changed by fingering the keys on a key-board; a rubber tongue and lips, to form the consonants, and when performing it is said to utter something like articulation in a monotonous organ note.

The tremendous amount of labor entailed in making these machines, together with the poor results obtained from them, acted as a deterrent in the prosecution of this branch of discovery and invention. The dream of the inventor was to make a machine with voice so powerful that it might be employed to command armies, and of articulation so perfect that it would serve for all time to perpetuate the pronunciation of nations. In both he was disappointed. There seemed to be no discoverable way of originating speech so powerful, so perfect, or so easily performed as that ready to hand in our vocal organs. And it will be remarked, as we proceed, that the epoch-making inventions and discoveries of the last few years have been made in new fields, and in the endeavor not to *origi-*

nate articulate sounds, but to *reproduce* them.

The Singing Condenser

It is not at all remarkable that the performances of such an instrument as the singing condenser should have been regarded at first with a feeling of incredulity; for it really appeared astoundingly wonderful that a revolving drum encased in tin-foil should utter passages from standard works, etc.; and in one eccentric member of the French Academy this incredulity was so strong that he declared to the laughing assembly that the sounds heard were the effects of ventriloquism. His astonishment must have been much greater still, however, when M. du Moncel gave a demonstration with a "singing condenser." Withdrawing to a room, in company with M. Faye, he closed the door and sang. His voice was heard in another room coming from a number of sheets of tin-foil interleaved with prepared paper, and connected with an induction coil.

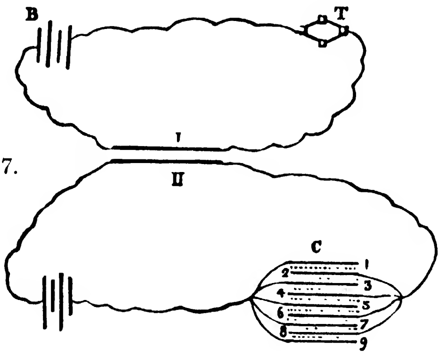


Fig. 7.

A condenser is a series of alternating sheets of tin-foil and some insulating substance like shellacked paper. These are generally placed in the oblong box upon which an induction coil rests. If there be, say, nine sheets of tin-foil, counting from the top, FIGURE 7 all those represented by odd numbers are connected at one side, and all the even-numbered sheets are joined up at the other. Wires leading from these two sets of metal sheets are joined up to the metal supports of what is

known as the contact breaker, a device employed for making the primary current intermittent. Varley, as we have before hinted, discovered some years ago that if such a condenser be connected to the secondary wire of an induction coil, while the primary includes a Reiss transmitter, then upon singing into the transmitter the notes are reproduced by the condenser. Our idea of the arrangement will be materially aided by a diagram. In Fig. 7 C represents the alternating sheets of tin-foil and an insulating substance. The sheets of metal are joined up to the secondary wire of the coil, which is here represented as one of a pair of parallel wires II. The primary circuit I includes the battery, B, and the transmitter, T. Upon singing into T, C gives out similar notes. By a slight alteration of conditions, it has been made to reproduce speech too. M. Dunand found that when a carbon microphone took the place of the Reiss transmitter, as represented in the diagram, and a battery was included in the secondary circuit along with the condenser, then speech could be reproduced—*i.e.*, if one talked to the carbon microphone the condenser reproduced the speech. These results were communicated to the French Academy by M. du Moncel.

We have now to turn to Preece's telephone, invented in 1880, an instrument of even greater simplicity than the one devised by Bell. The resistance which is offered by a wire to a current of electricity raises its temperature; so that if there be a rapid variation of the current, there will be a rapid variation of the temperature, an alternation of heatings and coolings. Heat expands or lengthens, cold contracts or shortens a wire. It is upon these principles, in addition to a few others already enunciated, that Preece's telephone is based.

Preece found in his experiments that wires 0.001 inch in diameter gave the best effects; and so far as materials are concerned, *very clear* sounds were obtained with platinum, *clear* sounds with palladium and iron, *faint* sounds with copper and silver, *very poor* results with gold, and *very variable* ones with aluminium. One curious result was that hissing sounds could not be reproduced by this means.

THOMAS YOUNG'S APPARATUS

In 1880 Thomas Young devised a simple apparatus consisting of a cylinder rotating on its axis and covered with lamp-black and a vibrating sound-producing metallic rod, one end of which was securely fastened while the other tapered to a point, was so set as to barely touch the lamp-black coating on the cylinder.

When the rod was made to vibrate, and thus produce a sound, and the cylinder was rotated, the point of the rod would scratch the lamp-black off the cylinder following a sinuous line, the form of which would vary according to the characteristic of the vibrations and hence of the sound.

A wavy circle was thus traced on the cylinder which permitted the study of the vibrations of the rod and enabled one to compare them with vibrations producing a different sound.

Lissajou, about the year 1850, devised an ingenious method by which he could examine the sound vibrations.

He fastened a tiny mirror on one of the two prongs of a tuning fork. He set an artificial source of light at a certain distance from the mirror so that a small pencil of light rays passing through a small orifice would strike the mirror, attached to the tuning fork. The pencil of light would be reflected upon another small mirror and again reflected by this second mirror upon a screen. An achromatic lens was placed in the path of the reflected rays so as to form a sharp image of the little hole through which the beam of light was forced to pass.

The tuning fork being at rest, a luminous point was seen on the screen but as soon as the fork was made to vibrate, an elongated image of the hole could be seen, due to the fact that the image of the point source of light was displaced very rapidly and according to the vibration of the fork. Through the phenomenon of persistence of vision all these rapidly succeeding images of the point of light could not be seen separately but would give the impression of a bright line on the screen, just as the tip of a red hot piece of charcoal when

rapidly moved up and down in the dark, will be seen as a glowing red line.

By rotating the tuning fork, and consequently the mirror attached to it, a sinuous bright line was to be seen which was a graphical representation of the vibrations of the tuning fork and, consequently, of the sound corresponding to those vibrations.

Lissajou was able, by these means, to conduct a very methodical investigation on sound vibrations and extended it to the investigation of combinations of sounds by submitting the source of light to two reflections by means of mirrors fastened to two tuning forks of equal or different pitch.

Another very interesting method of conducting this investigation was devised by Konig who transmitted the sound vibrations to a gas flame.

Konig, in 1873, devised a capsule divided into two compartments separated by an elastic membrane. One of the compartments he filled with gas which would be ignited at a jet communicating with the chamber. The gas was kept at a constant pressure in the chamber by a continual admission of gas.

At the other chamber Konig adapted a tube ending in a mouth piece through which the sound vibrations of an instrument or voice could be transmitted to the elastic membrane.

If the air within this second chamber was at rest, the gas flame would burn very steadily, but as soon as the elastic membrane would begin to vibrate the pressure within the gas chamber would vary according to the extent of the vibration and the gas thus unequally forced out of the jet would cause variations in the shape and height of the flame, which could correspond to the variation in the vibrations of the membrane, hence of the sound vibration which caused them.

In front of the gas jet and at a certain distance from it Konig placed a cube faced with mirrors, which could be made to rotate on its axis.

The phenomenon of persistance of vision again showed, when the cube was set to rotate, the vibrations of the gas flame in the form of a dented band of light which was of very

regular shape whenever the sound vibrations were proceeding from a pure note and of an irregular shape resembling tongues of fire of different heights when two notes or other impure sounds were investigated. Although the Lissajou's and Konig's methods were extremely interesting and permitted accurate study of sound vibrations they did not present the possibility of keeping a graphical indestructible record of the vibrations.

The French physicist Duhamel improved upon Young's experiment by preparing a cylinder traversed by an axle, with one handle at one end and screw-threaded at the other end. This cylinder he set vertically, held by two prongs pierced with holes, the lower one of which was threaded and then working as a fixed nut into which the threaded portion of the axle was engaged.

By turning the handle a *circular* and a *verticle* movement were thus simultaneously imparted to the cylinder.

Upon the cylinder Duhamel fastened a sheet of heavy paper covered with a thin film of lamp-black mixed with glue. A pointed steel rod was then fastened steady at one end and so set that its other tapered end would barely touch the paper.

The rod was then made to vibrate so as to produce an audible sound and when the cylinder was set in motion, at a determined rate of speed, the metal rod would scrape the lamp-black coating whenever it touched it and as in Young's experiment, trace an undulating line which represented graphically the vibrations of the rod.

Duhamel also set at a different height than the rod, a tuning fork, giving a known pure tone, and, at the end of one of its prongs, he attached a stylus barely touching the lamp-black coating.

By setting both the tuning fork and the metal rod to vibrate and the cylinder to rotate he would be able to record the vibrations of both at the same time and a single calculation would permit him, by comparison, to determine the exact number of vibrations imparted to the steel rod.

This method, though very ingenious, did not permit to make a record of the human voice or of any musical instrument.

Leon Scott, in 1857, constructed an instrument which he called the *PHONAUTOGRAPH,* which consisted in a barrel of eliptical form acting as a mouth piece, or better as the external part of the ear, which collects the sound vibrations.

The smaller end of the barrel was closed by an elastic membrane, which could be stretched to any desired tension. A feather stylus was fastened to the membrane and an ingenious device was proposed by Scott in order to insure its proper functioning. A drum similar to the one used by Duhamel was set horizontally so that the point of the feather would barely touch the lamp-black coating.

A circular and forward movement could be imparted to the cylinder at the same time, and the sound vibrations entering the barrel would set the membrane and stylus to vibrate and cause it to scratch a record upon the cylinder.

These ingenious instruments, and others which would require too much of our limited space to describe, permitted the study of sound vibrations and consequently of sound waves which lead the way to rapid and astounding progress.

Among the most interesting investigations we may mention those of McLeod and G. S. Clarke, who devised, in 1880, a Stroboscopic method, and those of Paul La Cour and Lord Raleigh.

Finally, in 1877, the American wizard, Thomas Alva Edison, gave to the world an astounding and truly revolutionary invention. We refer to the *"phonograph,"* the name of which was taken from the Greek words, "Phone" and "Grapho," the meaning of which is "to write sound."

Not only did Edison succeed in obtaining a graphical record of the sound vibrations, but he made it possible to *reproduce* them and thus *recreate* the sounds which he had, so to speak, "stored away."

The first Phonograph was essentially based upon Young's and Duhamel's principles. It consisted of a cylinder which could be made to rotate and move sideways at the same time, and of a vibrating membrane at one end of a mouth piece to which a small steel point was attached.

The merits of Edison's invention were derived from two

factors. He replaced the lamp-black coated paper by a sheet of tin-foil, and the vibrating membrane by a thin metallic disc. The steel point attached to the vibrating disc would gently press upon the surface of the tin-foil and engrave on it the vibrations which a sound would impart to the disc.

The disc which was later called the "diaphragm," was a very ingenious apparatus by itself, controlled by a light spring and small pieces of rubber tubing.

The position and pressure of the diaphragm could be regulated at will. After the desired sound was impressed upon the tin-foil the diaphragm and cylinder could be reset at their initial position and by setting the cylinder in motion the stylus would follow the indentations of the tin-foil and go through the same series of movements into which it was previously forced by the vibrating disc.

This movement was thus transferred to the disc which in turn would set the air within the mouth piece to vibrate and would thus originate sound waves very similar if not exactly equal to those which had originated the indentations in the tin-foil and a *reproduction* of the original sound was thus obtained.

The microscopic examination of the impressions engraved on the tin-foil disclosed that their section has the same appearance as the Konig's flames seen in the rotating mirror.

It is quite interesting to review a description of Edison's phonograph and the comments made by Ganot, one of the celebrated physicists of the epoch, who stated that: "In this way sound has been reproduced so as to be audible to a large audience; the articulation is distinct though feeble; it reproduces the quality of the person's voice who speaks into it, but with a nasal intonation. There is a great difference in the distinctness with which the various consonants and vowels are reproduced; the S, for instance, is very difficult."

PHONOKINETOGRAPH

It is fairly well known that the synchronization of the series of photographic pictures with the sounds emitted by

the subject being photographed was the main goal to which tended Edison's efforts.

It was in 1887 that Dickson, working then in collaboration with Edison, brought to light an apparatus on which the photographs were taken on a glass cylinder, previously coated with a sensitive emulsion, and synchronized with a cylinder sound record.

While Edison and Dickson were at work in the solution of the problems involved in their investigation, another great step towards the development of photographic procedure was being made. The possibility of preparing celluloid sheets of uniform thickness and transparency led some investigators, among whom George Eastman, to replace the glass plate by this flexible material as a support for the photographic sensitive emulsion.

The importance of this revolutionary advance in the art of photography is perhaps under-estimated by modern photographers and cinematographers, who have become so accustomed to its use and to the perfection of manufacture of this produce that the real portent of the discovery is little recognized.

Anyhow, Edison did not overlook the possibilities inherent to it and since George Eastman began to be able to supply him with short emulsion coated celluloid strips, he replaced the glass cylinder for them, and, in 1888, he completed a first apparatus which combined a film Cinematographic camera and a phonograph recorder. This apparatus was called the "*Phonokinetograph.*"

The synchronization and reproduction of the photographic and phonographic records were obtainable by mechanical means, and this explains the little success of the process which never entered the field of commercial exploitation.

The problems inherent to the process and which Edison and Dickson set to solve, were mainly those pertaining to the synchronization of the photographic record with the sound record. The task was arduous at a time when both apparatus, the motion picture camera and the phonograph were still in their embryonal stage..

The laboratory experiments of these two indefatigable workers remained as such, and only the withdrawal of motion pictures from the peep-hole box and their presentation upon a screen seemed to open new horizons for the development of the ambitious dream.

It must be kept present to the mind that the phonograph of these times, though giving a marvelous display of a man's intelligence and love for Science, was nevertheless a mere toy when compared with the instrument of today, and motion pictures were but a crude attempt to give an impression of motion obtained with inadequate instruments and facing a number of undreamed of problems. Nevertheless, the promises that the two infants held in store were amply justified by the unselfish work and the faith of few enthusiasts.

The brilliant achievements of the Lumiere Brothers, in 1896, at which time motion pictures were finally shown to an audience by projection upon a screen, spurred scientists all over the world, and, in 1898, we find a Frenchman, Mr. Ducom, developing a synchronized system through which the phonographic record was heard by means of a head piece. Each seat of an auditorium was equipped with such an instrument.

In 1900, another pioneer in French Motion Pictures, Mr. Gaumont, presented a phonograph and a motion pictures projector mechanically synchronized. The two records were, however, to be made separately, due to a number of mechanical limitations which seemed unsurpassable at that time.

In America, a mechanical genius, Daniel Higham, was in the meantime inventing a loud-speaking phonograph, and Edison, always anxious to gather around himself the most promising talents, engaged him and from their association a mechanical synchronizer was born through which for the first time a picture and a sound record were made simultaneously, and presented to an audience limited in number, it is true, but nevertheless an audience which did not have to depend upon individual head pieces or individual picture apparatus for seeing and "hearing" a motion picture.

Pathe Freres, in France, also tackled the problem, and succeeded after several years devoted to experimentation, to ob-

.ain a remarkably good synchronization in both the taking and the producing of sound pictures which followed the fate of all other similar systems, that is to say, it aroused the interest of the scientists and researchers, but remained within the realm of laboratory experiments.

It is quite necessary that we now depart temporarily from the field of sound and photographic analysis and synthesis in order to rapidly survey developments of a different nature but which were called to play an extremely important part in sound pictures. We refer to the transmission of sound over a distance. The ever-increasing knowledge on electromagnetism led Graham Bell, in 1876, to the invention of the telephone.

The basis upon which this apparatus was constructed was the known fact that a magnet can produce induced currents in a metal circuit. Graham Bell wound a coil of wire around the pole of a permanent magnet, leaving certain space between it and the coil. In front of the magnet and at a small distance he placed a thin disc of soft iron which could be set to vibrate by sound waves impinging upon it even as the diaphragm in Edison's phonograph. The coil was extended by two wires connecting a similar instrument set at a distance, one of the wires being most of the time substituted by the earth.

Now, if a magnet is held stationary in a wire coil, no effect is produced, but if the magnet is rapidly withdrawn or introduced in the coil, or if a change is brought on its magnetism, electrical currents are developed in the coil itself sufficient to be detected by a galvanometer.

The necessary variations of magnetism are introduced into the permanent magnet of the telephone by the vibrations impacted to the diaphragm when sound waves strike it. The current thus produced flows in alternate direction, and since the diaphragm itself becomes magnetized by induction its varying positions also give a rise to an alternating current in the coil, which flows in the same direction as the current produced by the permanent magnet.

These currents are transmitted through the wires to the second apparatus, the diaphragm of which when used as a reproducer, that is to say, sets in motion the particles of air

surrounding it, this motion is necessarily equal to that imparted to the air particles by the sound vibrations at the transmitting end, and therefore are a reproduction of these same vibrations, which the ear detects as sound.

The above brief and purposely simplified description of Graham Bell's telephone is but an introduction of new elements without which the modern art of sound synchronized pictures could not exist.

After the invention of the telephone, Graham Bell visualized and brought into practice the possibility of transmitting sound at a distance without the use of connecting wires and through the agency of light.

Bell took advantage of the remarkable property of Selenium to alter its electrical resistance proportionately to the intensity of the light to the influence of which it is submitted.

In order to bring about the necessary alterations in the intensity of a source of light striking what we would call a Selenium Cell in rhythm with pre-determined sound waves, Graham Bell devised an apparatus which he called the *"Photophone."*

This apparatus consisted of an optical system condensing a source of light, natural or artificial, to the back of the vibrating diaphragm of a telephone transmitter. The surface of this transmitter was polished so as to have the high reflective power of a mirror. When the diaphragm was at rest it would be so set as to reflect the light in a desired direction.

The reflected rays were collected by a lens which would force them to follow paths parallel to each other. This beam of parallel rays was made to strike a parabolic concave mirror, the reflecting surface of which would force them to converge at its focal point.

A Selenium Cell was placed at this point.

This cell was constructed of a number of thin brass discs alternated with smaller mica discs. The interstices between the several brass discs, which resulted from the fact that the mica discs were of a smaller diameter, were filled with melted Selenium.

The Selenium cell, or resistance, as we may call it, was

made to be part of an electric circuit comprising a telephone receiver and a battery.

When the diaphragm of the transmitting instrument was at rest the rays of light, reflected by the surface of the mirror, would strike the Selenium cell at the maximum of their intensity; but, as soon as the transmitting diaphragm was made to vibrate, the parallelism of the rays of light would be destroyed and due to the change thus brought in the angle of reflection of the rays of light incident upon the parabolic mirror, the degree of concentration of the reflected light striking the Selenium resistance would be altered. This would alter the electrical resistance of the Selenium and the strength of the current flowing in the circuit would thus be submitted to rapid changes in accordance with the vibration of the transmitting diaphragm. The diaphragm of the telephone receiver would in turn vibrate in accordance with the changes of strength thus brought about in the current flowing in the circuit and therefore, in correspondence with the vibration imparted to the receiving diaphragm.

If some one would speak into the receiving apparatus his voice would thus be transmitted at a distance without the need of intervening wires and through the influence of the light rays.

Recording Voice on Film

Thus far the "singing arc light" or "talking arc light" had been used for voice transmission only. Ruhmer now began his experimentation in using the arc light for recording the voice upon a sensitized photographic film. He passed the sensitive film rapidly before a narrow slit through which the light of the flame could strike it. The slit was about 1/16 of an inch in width and of such a length as to admit of the seeing of both the carbon points through it when the eye was in the position of the photographic film. With this apparatus he succeeded in getting records which were sufficient to satisfy him that the vibrations of the flame were recorded, but the record was not sharply enough defined to admit of reproduction.

By substituting for the slotted metal a cylindrically ground

lens this difficulty was overcome. It is the property of a lens of this character to produce at its focus an image which is not at all reduced in size lengthwise of the lens, but which is reduced to the mere thickness of a line in the other direction.

Placing the cylindrically ground lens with its axis across the line of motion on a long photographic film, the vibrating light of the speaking flame was thrown upon it. With proper motive apparatus the film was moved rapidly in front of the lens. The result was a record formed in lines so fine as to repeat distinctly practically every vibration of the voice of the speaker. The film having been developed and fixed forms a record which can be retailed indefinitely. The reproduction of the voice from this record is accomplished by a reversal of the process by which the record was produced.

To make the record talk it is again mounted upon its rollers and wound from one to the other so as to be passed rapidly in front of the light of an arc lamp. The light passing through it falls upon a selenium cell and this in the manner already described changes its variations into vibrations on the disc of a microphone.

We now come to the period when attention was given to the synchronizing of the voice with the picture.

Synchronizing Voice With Picture

The production of imitation sounds or effects is quite a different problem to the reproduction of the actual sounds themselves. In the latter case the sound record has to be made and reproduced with the picture. It must, moreover, keep in time with the picture; that is to say, there must be "synchronism" between the sound and the picture records. The ordinary victrola record is obtained by the action of a vibrating membrane which produces a series of indentations in a soft surface of wax. These indentations are used to reproduce the vibrations of a membrane, and thereby reproduce the original sounds. Stripped of all refinements, this is the essential principle of the victrola. If, then, a record of the sounds can be made simultaneously with the photographic

record, it would not at first sight appear to be difficult to reproduce them in synchronism. The first of these problems is rendered difficult by reason of the limitations of the sensitiveness of the recording victrola. The recording instrument must be within a certain range of the sounds, and for a speaker or actor the range is not a large one, and it is difficult to get the instrument near enough and keep it outside the picture view. Accordingly another method had been resorted to, which is applicable in a large number of cases. The music record is taken first, and the picture film is produced to the accompaniment of the record. To succeed with this method it is obviously essential that the speaking, singing or acting should synchronize with the sound record for synchronism between the same return and the picture film to be possible. A further limitation arises from the size of record obtainable. A small or short record means a short film. The size and length of an ordinary record is very limited, and for a speech, sketch or piece of any material length, several records are necessary, and these would need to follow on at the proper time. Having obtained the record and picture film, the problem of reproducing them synchronously is still a formidable one. It is, of course, theoretically possible for the projectionist to keep his eye on the screen and his ear on the victrola, and to control the projector or victrola so as to maintain synchronism. This, however, throws an additional responsibility on the already over-burdened projectionist, and is not a practicable method. Accordingly, either an auxiliary device is necessary to automatically indicate to the projectionist if the synchronism is being maintained, or some means by which the running of the projector or victrola, or both, is automatically adjusted to maintain synchronism.

In one of Gaumont's earliest methods, introduced in 1902, a motor was used to drive the projector. This motor was electrically controlled from the victrola. The victrola drives a shaft, carrying collector rings, of an electric circuit; and carrying also rotating brushes, which rub on a divided collector, the sections of which are connected to the stator of the motor. The next step in advance is the use of synchronized

motors for driving both the victrola and the projector. Mester, in Germany, appeared to have been working on these lines, and special types of motors were used. The two motors of identical design and the same power were driven from the same current, and in order to better maintain synchronism the motor armatures each had a number of sections which were connected in pairs. A switchboard near the projector included a starting switch, whereby the victrola was first set in motion; and when the record commences, the disc operates a switch to start the projector. A voltmeter on the switchboard indicated any want of synchronism which was corrected by accelerating or retarding the projector. This is effected by coupling the projector with its driving motor through a differential gearing, which was operated from a separate motor. This latter motor was started by an auxiliary two-way switch, so that the differential could be used to retard or accelerate the projector to restore the synchronism. The results obtained with the Chronophone were extremely satisfactory, and by the use of the Auxetophone, in which the sound was intensified by means of compressed air, the possibility of the Chronophone in large halls was looked upon as a possibility, as was evidenced by its use at the old Hippodrome in Paris, which had a seating capacity of over four thousand.

The use of indicators for automatically indicating to the operator any want of synchronism has been adopted by many inventors in various ways. In one of the earliest, two indicating elements were used, one consisting of a disc, rotated directly from the projector and the other a concentric pointer, rotated by an electro-magnet, which is intermittently energized by a circuit, completed on every revolution of the victrola spindle by means of a cam on the spindle. The disc carries a mark, and so long as the mark on the disc and the pointer are coincident, synchronism is being maintained. If the pointer leads or lags, the projector is speeded up or slowed down accordingly to restore synchronism.

There is undoubtedly a comparative simplicity in such a method as this, of which there have been many varieties. In one by Thomasin, a pointer is rotated intermittently by a

pawl and an electro-magnet energized from the shaft of the victrola. The electrical escapement is mounted on a coaxial disc which is rotated in the opposite direction from the projector shaft. So long as synchronism is maintained there will be no movement of the pointer, and any movement of the pointer indicates the adjustment necessary for the projector. With this apparatus there is a single indicating element only.

Another somewhat different method and apparatus, invented by Mr. Jeapes, which bears the stamp of extreme simplicity, was brought out as the Cinephone by the Warwick Trading Company. In this method a rotating pointer is attached to the victrola and driven by it. The victrola is positioned so that a record of the rotation of the pointer is produced on the film at one corner thereof. The victrola is placed near the corner of the projection screen, on which the reproduction of the pointer appears. The projectionist then controls the projector so that the reproduction maintains the same angular speed as the pointer.

A difficulty with several synchronizing devices where an indicating pointer is used arises when a film breaks or is damaged, and a section of it has to be cut away. In such cases it is necessary to slow down the projector until the victrola catches up, but there is no visible indication when synchronism is restored. With the Cinephone, however, the restoration of synchronism is indicated by the reproduction of the pointer on the screen.

In another type of device, by Count Proszynski, the projector is coupled with the victrola by connecting a spindle of the projector with an air-pump, the air outlet of which is regulated from the phonograph in such a manner that when synchronism is faulty the bellows actuate a brake or otherwise control the speed of the projector.

Lauste's Method

In another and altogether different system, invented by Mr. Lauste in 1906, the sound as well as the picture are simultaneously recorded on the film.

In Lauste's method the sound record is made photographically. A microphone transmitter, such as is used for collecting the sound waves at concert halls for transmission, or alternatively, one or more horns or trumpets, *a*, FIGURE 8, connecting with any ordinary loud-sounding telephone or microphone transmitter, *b*, receives the sounds, and transmits them over an electric circuit, *c*, *d*, to the receiver in the camera, *A*. At the receiver is an electro-magnet, *B*, and the varying electric currents produced by the action of the sound waves in the microphone transmitter *b*, vibrate a slotted diaphragm which moves between a fixed light and a fixed slotted diaphragm. The vibrations of the diaphragm corresponding to the sound waves produce variations in the light openings through the diaphragms and consequently variations in the intensity of

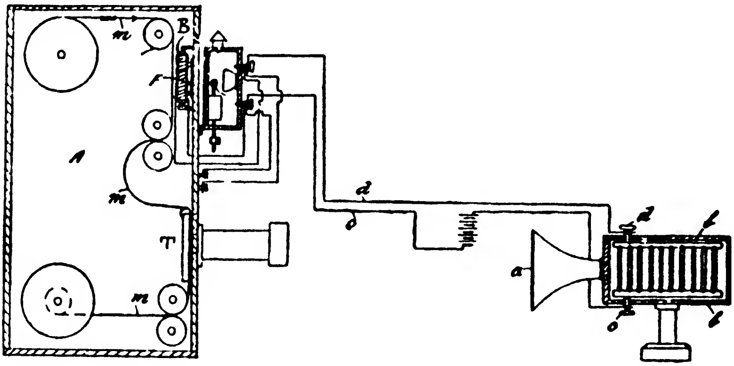


FIG. 8.

light falling on the sensitive film *m*, behind the diaphragm are produced. The sensitive strip on which the light falls, is adjacent to the picture area of the film and, when developed, forms the sound record. The sound record must be made while the film is moving continuously, before or after it is fed intermittently through the gate *T* of the camera. It will thus be seen that the sound record on the film is a few picture lengths behind the corresponding section of the picture record. To reproduce the sound record, use is made of the fact that the resistance or conductivity of a selenium cell, when included

in an electric circuit, *b*, varies in accordance with the intensity of light acting on it. In the projector, FIGURE 9 the film passes between a lamp, *p′*, and a selenium cell, *r*, in circuit with a loud-sounding microphone or telephone, *H*. The variations in the current produced by the variations in the light intensity

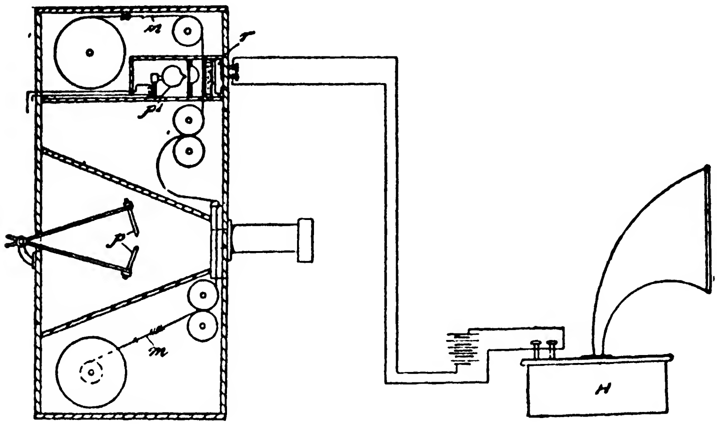


FIG. 9.

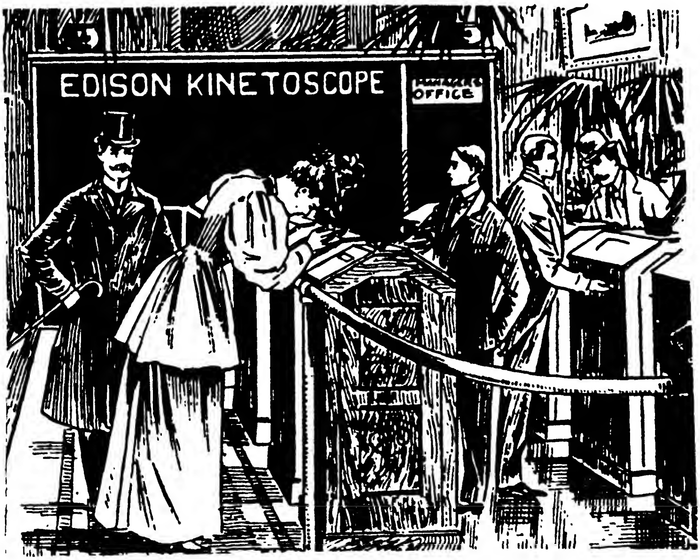
transmitted through the sound record *o*, and falling on the selenium cell, cause a corresponding variation of the sound membrane in the loud-sounding microphone or telephone, *H*.

In 1910 Edison used a device consisting of a phonograph on the stage, coupled by a wire-driven belt with the projector in the booth, in an effort to obtain synchronized sound effects with pictures. The entertainment ran for some sixteen weeks in the B. F. Keith theaters, but had no further commercial success.

In June 1912 C. E. Fritts applied for a patent covering an invention relating to recording variations or pulsations in sounds, light or electric currents in a permanent or tangible form and reproducing same at will not merely at the instrument alone but also at any other instrument suitably connected therewith.

In May 1913 Elias Ries submitted his sound record method and method of reproducing photographic sound records. The

invention for the sound recording method relates to methods for the production of photographic records of sounds, whether vocal, musical or of other character, and of type such that the original sound can be accurately reproduced therefrom with facility. The invention, although in certain broader aspects thereof applicable to the preparation of sound records alone, has its preferred application to the production of talking picture film record, that is, to moving picture films bearing a succession of photographs of successive stages in the action, and taken in usual manner, and provided with one or more continuous sound records laterally of the picture, which represent the amplitudes and phases of vibrations of the sonorous action, such as music, speech or the like, occurring and recorded simultaneously with the visual action.



MOTION PICTURE PIONEERING

In the field of early workers trying to perfect a motion picture projector, were William Kennedy Laurie Dickson, an Englishman, though born in France, who came to this country to work for Edison, and who had much to do with the development of the Edison peep-hole machine and the Edison moving picture camera, Major Woodville Latham and his two sons, Otway Latham and Gray Latham, C. Francis Jenkins of Washington, D. C., Thomas Armat also of Washington, D. C., Jean LeRoy of New York City and others

In Lyons, France, the Lumiere Brothers, and in England, Robert Paul, were also working trying to perfect a projector.

Let us briefly record the respective efforts of these men.

WOODVILLE LATHAM

We will first deal with Major Lathams efforts, we give him this premier position, because he was undoubtedly the first to show a projected picture commercially. Latham was a southerner, a college professor at the University of West Virginia, where he taught chemistry. His first contact with motion pictures was through his sons, their interest having been aroused by their visit to one of the Kinetoscope Parlors on Broadway in New York City, where after dropping the coin in the slot to view the peep-hole pictures, they visualized the possibilities of showing the moving picture on a screen. Having interested their father, a company was formed, under the name of the Kinetoscope Exhibition Company, for the purpose of renting

Kinetoscopes and films and using them for the showing of prize fight pictures.

Lathams opened their first parlor at 83 Nassau Street in New York City, in August 1894, with moving pictures (peep-hole) of the Leonard-Cushing prize fight, later following with a picture showing a fight between Jim Corbett and Pete Courtney, this fight being specially posed for the movie camera, by Enoch Rector, a partner in the Latham enterprises.

These pictures soon outlived their drawing power, and in September 1894, one of the sons approached the father, asking help in designing apparatus capable of

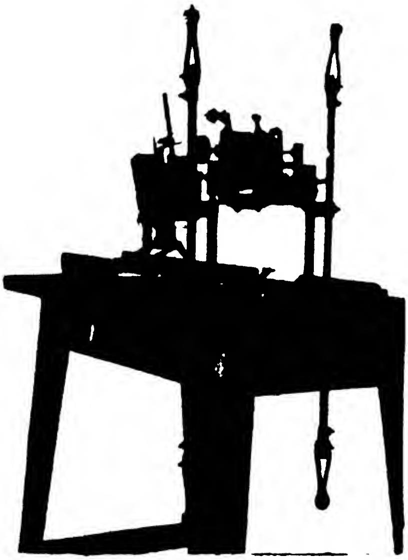


Fig. 10

projecting the pictures onto a screen, so that they could be viewed by many people at the same time. Eugene Lauste, who had experience with Edison was engaged as a mechanic, and some time later, still another of the Edison personnel, Laurie Dickson, lent his support, first in developing a camera and later, the projector.

This projector, named the Pantoptikon, shown in Fig. 10, was used at a press showing of pictures projected onto a screen, on April 21st, 1895. Lathams then opened a store room at 153 Broadway, New York City, where motion pictures were first projected before a

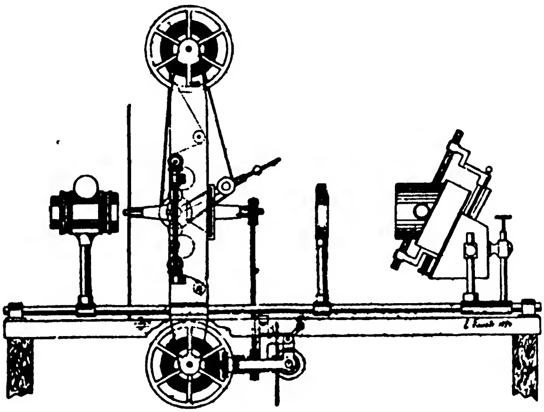


Fig. 10A

paid audience on May 20th, 1895. These projected pictures were poorly illuminated, were most unsteady, and the flicker was so bad that it was possible to make out the photographic details only with great difficulty. All concerned, including the Lathams knew that the venture was a commercial failure, unless a number of refinements could be added to secure a projected picture that would be accepted as satisfactory by a paying audience.

Edison learned of the Latham Pantoptikon and the performance of May 20th, through the account carried in the New York newspapers, and immediately claimed that the Latham machine was an infringement of the Edison Kinetoscope (peep-hole) machine. Edison threatened to bring suit, not only against Latham, but also against all those who used the Latham machine.

In a letter written to the New York Sun, dated April 22nd, 1895, Woodville Latham denied that the Pantoptiken was an infringement of the Edison machine,

and made a number of counter charges against Edison, ending his letter with a paragraph reading — "If Mr. Edison can project pictures of moving objects on a screen, as he says he can, why does he not do so publicly as I have done, and do this at once".

While Edison did not take up this challenge, these charges and counter charges were the beginning of legal proceedings, seeking to establish patent rights or priority rights covering projectors and cameras, stretching over many many years, practically until the disolving of the Motion Picture Patents Company, about 1913.

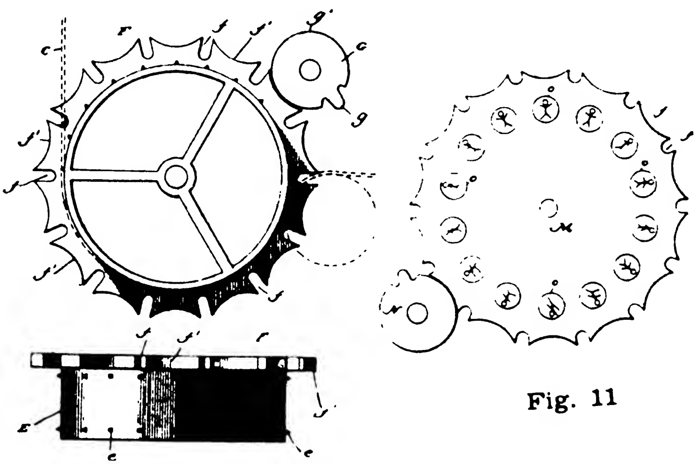


Fig. 11

A later product of Lathams was the Eidoloscope Projector, Fig. 10A.

Before leaving the Lathams, let us state that it was Enoch Rector, Lathams partner, who first used the slack loop of film, above and immediately after the intermittent movement when threading the camera, this loop became known as the "Latham Loop" and is still used to-day in threading both cameras and projectors.

ARMAT and JENKINS

In the year 1894, the year that Edison Kinetoscopes were finding a ready sale throughout the world, Thomas

Armat and Francis C. Jenkins, both living in Washington, D. C., and both students at the Bliss Electrical School there, became acquainted, and found that their interests lay along similar lines, namely, that of developing a machine capable of projecting motion pictures. A partnership was formed, and from their joint efforts, a projector was built, employing the use of an intermittent movement. A patent was granted to Ar-

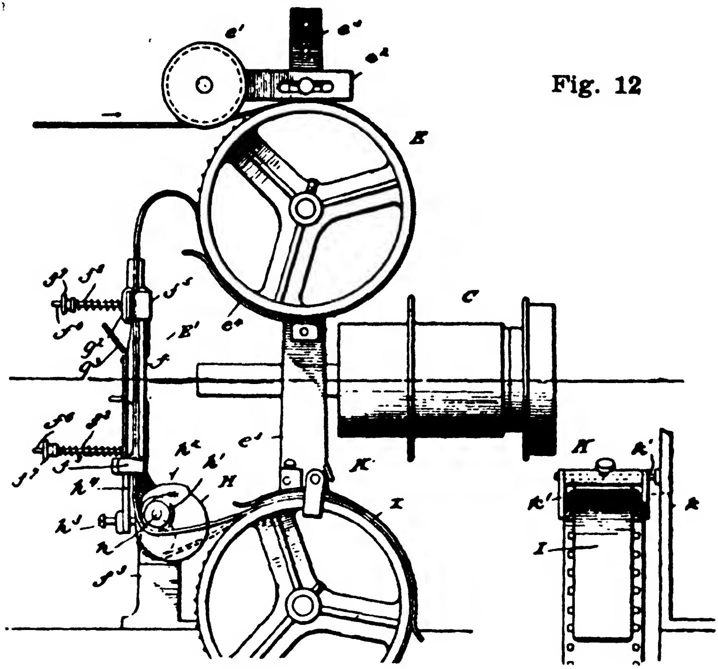


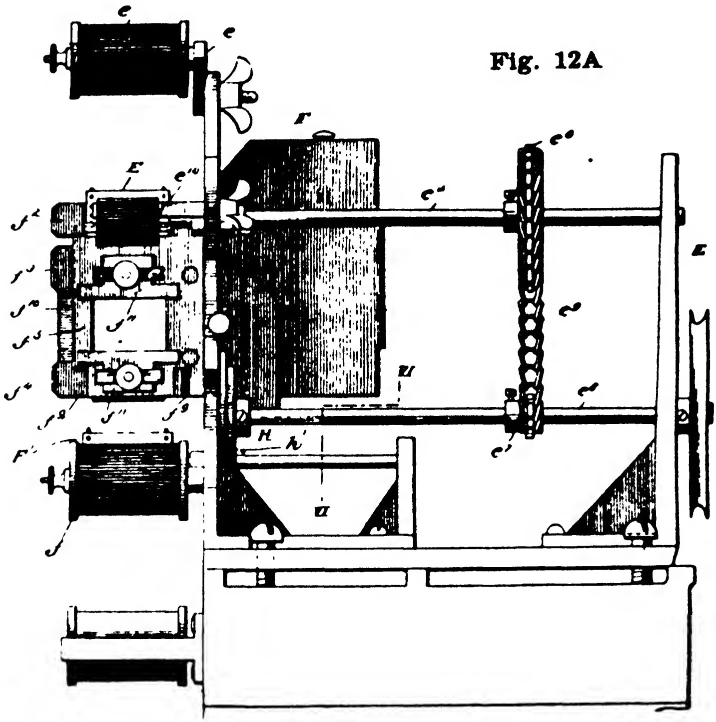
Fig. 12

mat and Jenkins covering this projector in July 1897, application for the patent having been made in August 1895. Fig. 11, shows the illustration which accompanied the patent application, and from this drawing it will be seen that an arrangement had been made providing for a long period of rest and illumination, and a quick shift of pictures.

The Edison films, made for the peep-hole machines were used in the Armat and Jenkins projector, but as these films were taken at the rate of forty frames per

second, the projector could not run the film through fast enough to secure proper registeration on the screen, the projector speed could take care of only about twenty frames a second, the result was that the projected pictures were given a grotesque effect.

Fig. 12A



Armat and Jenkins first used their projector commercially at the Cotton States Exposition held in Atlanta, Ga., in September 1895. Shortly after this, Armat and Jenkins broke the partnership agreement, each then going his own way. Armat rebuilt the old projector, added a loop forming device which greatly lessened the strain on the film. It is conceded that Latham was the first to employ this loop in the camera, but to Armat goes the credit of being the first to use it in projectors.

Early in December 1895, Armat gave a showing of

the redesigned and rebuilt projector in the basement of his Washington, D. C., office, before F. R. Gammon, of the firm of Raff and Gammon of New York City, who were agents for the Edison peep-hole Kinetoscope and the Edison moving picture films. After the demonstration, Gammon returned to New York and gave a glowing account of the performance of the projector to Edison, which resulted in having Edison agree to

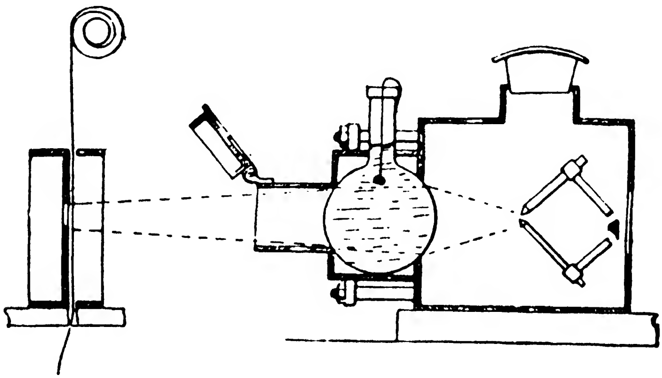


Fig. 13

look the projector over, with the possibility of Edison building the projector for commercial use. Armat put on a special showing in Orange, New Jersey, on April 3rd 1896, this was for Edison and the invited press, the result was that arrangements were immediately made to book the projector and films into Koster and Bial's Music Hall, at 34th Street and Broadway, New York City, beginning April 21st. There was some delay in getting the projector connected up and the pictures were not shown until the night of April 23rd, 1896.

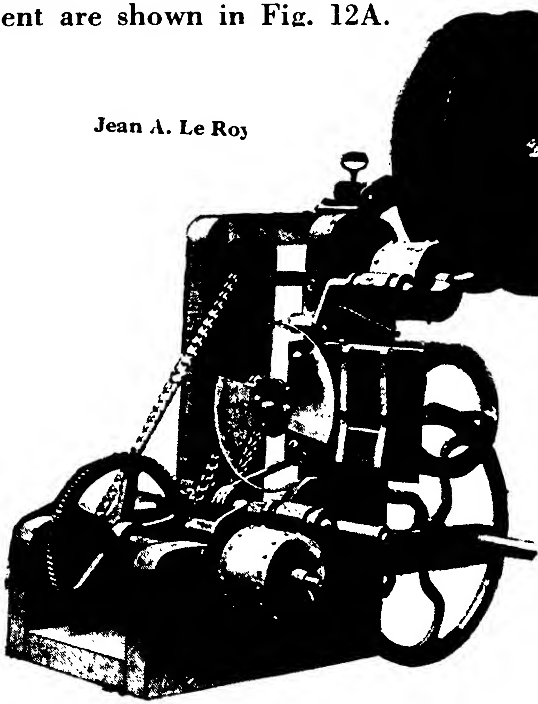
Thomas Armat operated the equipment himself, showing a number of short subjects originally made by Edison for the Kinetoscope, and one or two films made by Paul of London, England. The projector had been named the Vitascope by Armat, and it was billed during the music hall engagement as Edison's Vitascope. The Edison name being tacked on to the projector for

commercial purposes.

This showing of motion pictures at Kosters and Bial's Music Hall on April 23rd, 1896 was the first showing of motion pictures in any theater, in this country. Fig. 12, shows the drawings which accompanied the patent application covering the Armat Vitascope. This was issued in the name of Thomas Armat and not in the joint names of Armat and Jenkins, as was the earlier patent.

Some time later, Armat developed a projector, using a Geneva Cross as the intermittent movement, this was patented in March 1897, and details covering this patent are shown in Fig. 12A.

Jean A. Le Roy



While credit for the showing of the first projected motion picture before a paying audience must go to Latham (May 20th, 1895) in their store show at 153 Broadway, yet Thomas Armat must be credited with the first successful commercial showing of a projected motion picture, in the United States, (April 23rd, 1896).

JEAN LE ROY

Jean Le Roy while an apprentice to a photographer in Chambers Street in New York City, used to earn a little extra money by operating a stereopticon in and around New York and New Jersey, in his spare time. His contact with the stereopticon gave him the idea

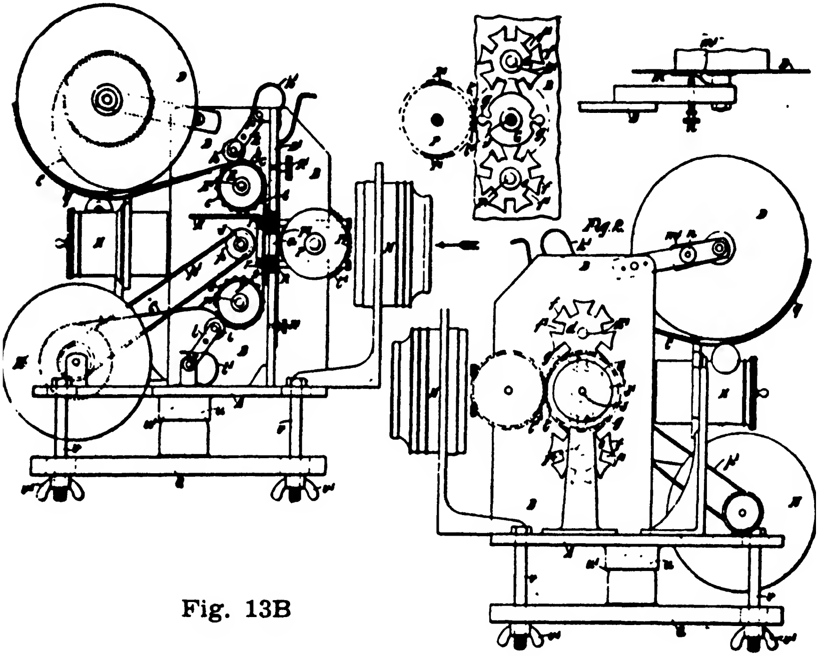
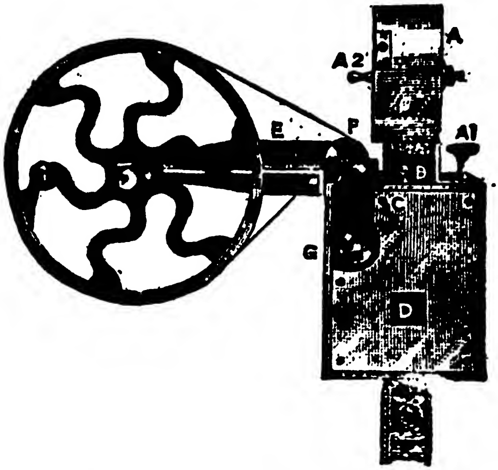


Fig. 13B

of trying to develop a projector for the showing of pictures in motion. His claims that he perfected a projector as early as 1893, using an unperforted film, cannot be checked by any existing records. The writer who often talked with Le Roy just prior to his death, was convinced that he did yeoman pioneer work and that it was possible that such a projector was built by him, but nowhere could be found records showing that the projector was ever used in public. A projector built by Le Roy in the 1900's can be seen in Fig. 12B.

So as not to run ahead of our story, we will now

have to leave this country and visit England and France. Let us first take up the early motion picture history of France.



Riley's Kineoptoscope, developed in Bradford, England, 1895

LUMIERE BROTHERS

As in America, it was the introduction of the Edison Kinetoscope peep-hole machine into France that started the Lumiere Brothers in the moving picture business. Of all the early inventors in the field, the Lumiere Brothers were the best fitted on account of their training and experience in the photographic business, a business they had successfully ran for a great number of years in Lyons, France. One of the brothers while in Paris on business, paid a visit to a Kinetoscope parlor at 20 Boulevard Poissoniere, and after viewing the pictures through the peep-hole got the idea that there must somewhere, be a connection between this new peep-hole form of entertainment and their photographic business. They too, could foresee the great possibilities of a machine capable of projecting these motion pictures onto a screen. and started work with this idea in

mind.

Their first difficulty was to obtain films with which to experiment, so they first built a camera and produced their own. The Lumiere's found that the forty exposures per second rate, used by Edison in his peep-hole machine, was too fast for their purpose, and after trying several different speeds of exposure per second, they decided on an exposure and projecting speed of 16 frames a second. This rate became the standard until the advent of the sound picture in 1928.

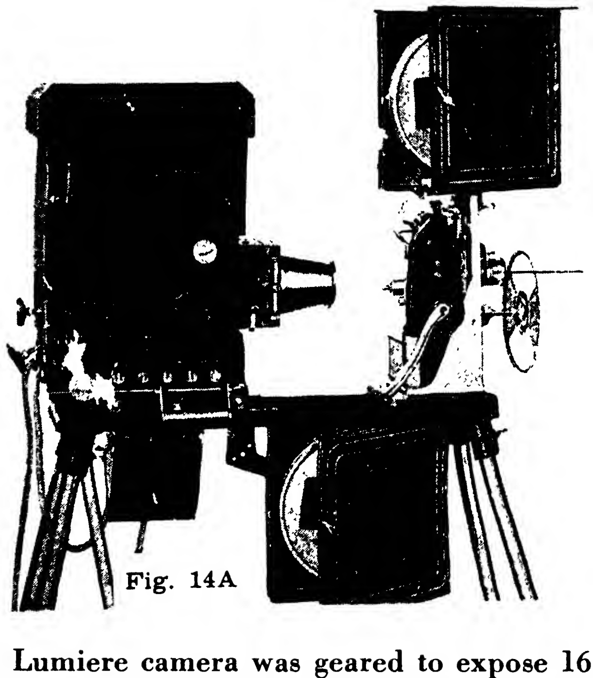
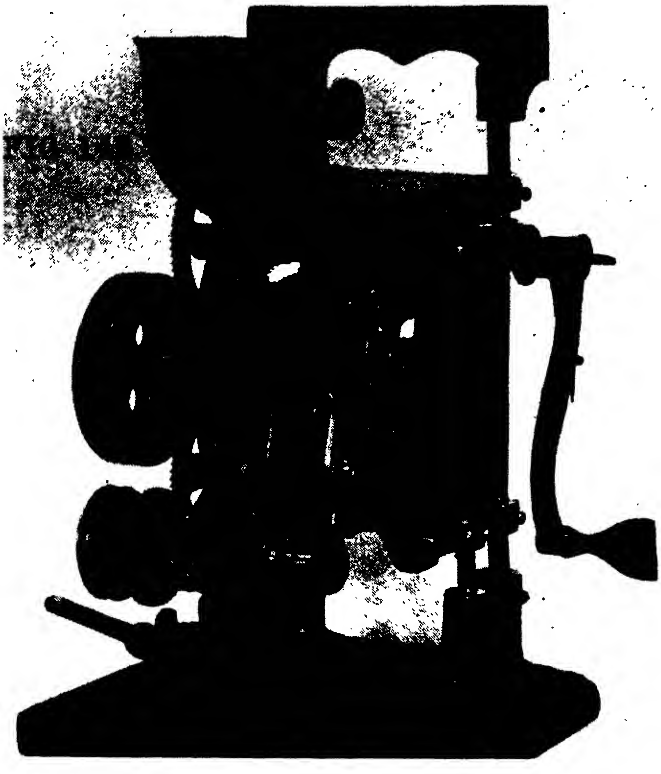


Fig. 14A

The Lumiere camera was geared to expose 16 frames (one foot) of negative film to every two turns of the camera crank, this too, was standard practice for several years. With the perfection of the camera, the Lumiere Brothers had both feet firmly set in the motion picture business. This camera was a small portable affair that could easily be carried and operated anywhere, as against the camera used by Edison, which was anything but portable, it required several men to lift it, and

could only be operated away from the specially built studio with great difficulty.

Thus while Edison had to have all his pictures made within the confines of his small studio, theLumiere's had a much greater field, being able to take pictures almost



anywhere and of any topical event. The result was that the Lumiere films were soon in great demand, not only abroad but in this country.

The Lumiere projector, shown in Fig 13, was ready in March, 1895, patents having been granted in February of the same year. A demonstration was given before the Society for Encouragement of Industries, and on December 28th, 1895, Lumiere opened in the basement of the

Grand Cafe in Paris, with the first commercial showing of projected motion pictures in France.

From the illustration Fig 13, it will be seen that the Lumiere projector was equipped with an arc-lamp and instead of using the condensers, Lumiere employed a spherical flask filled with water. Besides acting as a condensing medium for the light rays, this water flask

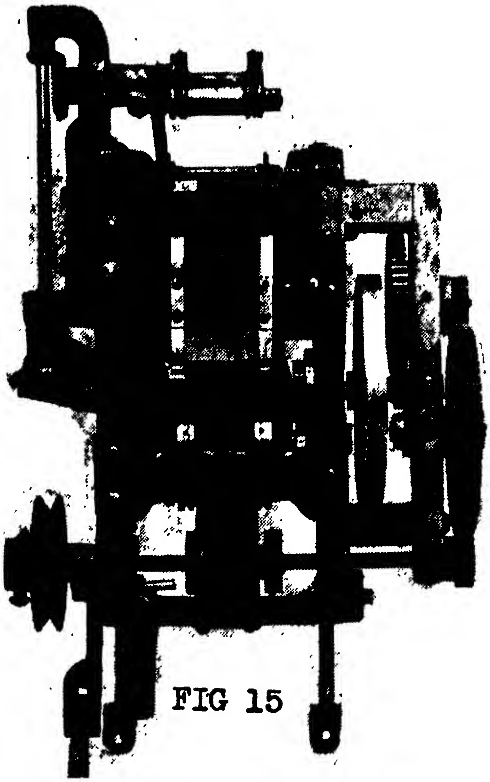


FIG 15

also served as a heat absorber. The small black object seen suspended in the top of the flask, is a piece of pumice stone, this was used to regulate the boiling of the water. To the projectionist of to-day this may seem a rather crude and elementry method, however, as a matter of record, the writer worked with a similar water

cooler and condenser as late as 1917, this was used on a projector named the Vivatarg, a projector whose operations, starting, stopping and re-starting was controlled by sound waves. One of these projectors was installed in the basement of the Strand Theater on Broadway around 1916, while another operated by the writer was used at Camp Upton L. I. during the first world war. This projector is described in detail in another chapter in this book.

Now across the English channel to England, to let us take up the work done by Robert W. Paul.

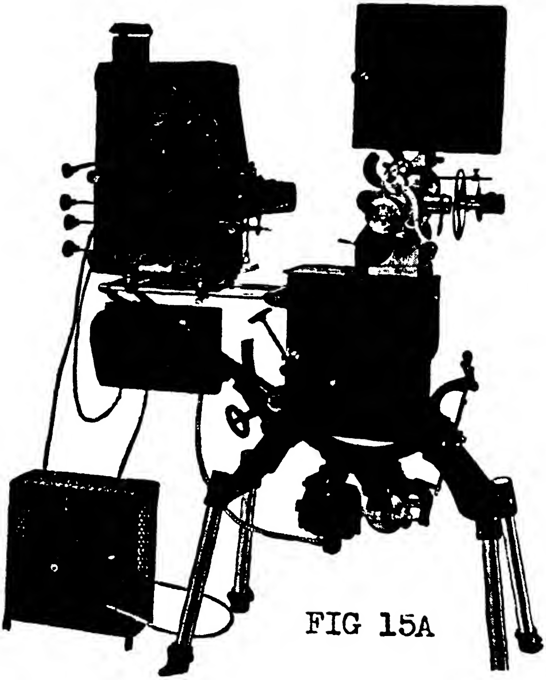
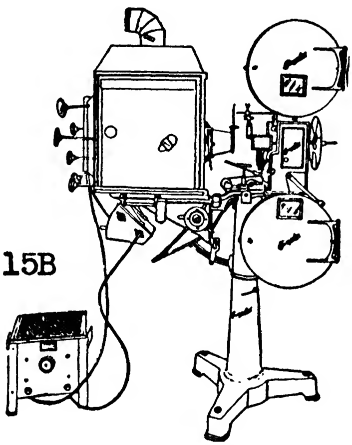


FIG 15A

ROBERT W. PAUL

Paul was a manufacturer of electrical and scientific instruments having been in this business at Hatton Gardens, London, England since 1891. His interest in motion pictures, was aroused by contact with two Greek salesmen, who while over in the United States had seen

and purchased two of the Edison Kinetoscopes and had brought them back with them to London. The operation of these two machines proved profitable, so the two Greeks approached Paul, asking that he build others for them, using the two machines as models. Paul checked at the British Patent office and found that Edison had not taken out patent papers on the Kinetoscope, thus leaving the English field free to all who wished to build. Paul built several of the peep-hole machines, fifteen of these were placed in Earl's Court Exposition in London, where they all coined money for Paul.



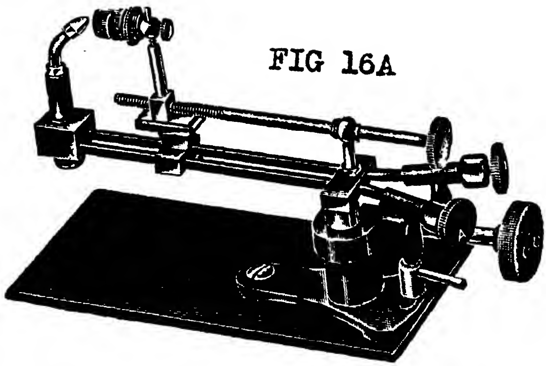
15B

When Edison learned that similar machines to his Kinetoscope were being built and sold in France and England, he decided to cut off the supply of Kinetoscope films to both countries, thinking by so doing, he would render the foreign built machines useless after the stock of films then in England and France were exhausted. Paul, however, did not want to lose this lucritive source of income, and so made arrangements to make pictures. This of course meant that he had to build not only cameras but printers and perforators. While working on these necessary machines, the idea of building a projector to project the picture onto a screen came to Paul. The first Paul projector was de-

scribed in the English Mechanic dated February 21st, 1896. The projector, would be termed to-day the "head" or the "mechanism" and it was intended to be used with any steropticon lantern, a great number of these then

FIG 16

FIG 16A



MIXED GAS LIMELIGHT JET

being in use. The intermittent was a seven-toothed star-wheel, which in turn was driven by a steel finger-wheel. This intermittent can be clearly seen in the photograph of the Paul projector, Fig 13A. A series of drawings of

the Paul projector, which accompanied the patent application is shown in Fig 13B. Paul named his projector the Theatrograph, he gave a demonstration at Finsbury Technical College, London, on February 20th, 1896.

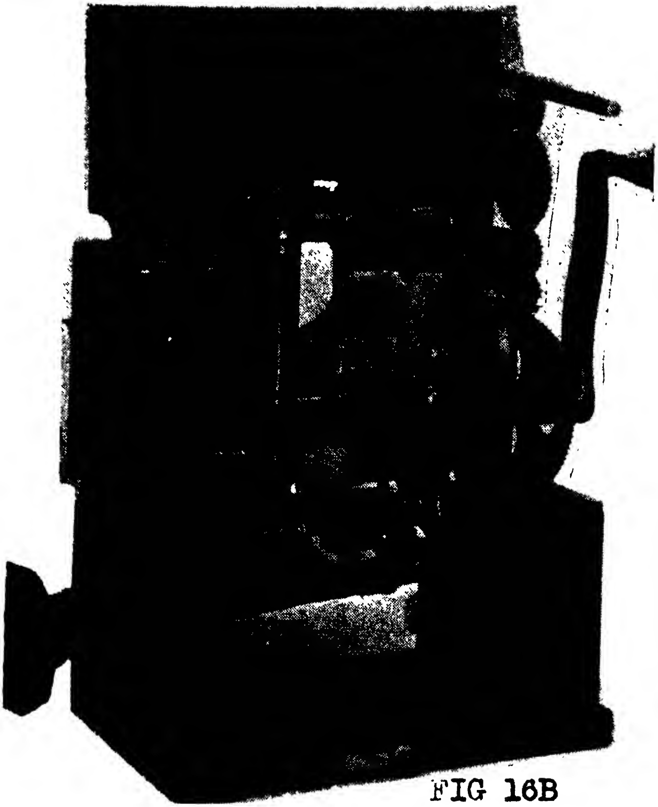


FIG 16B

In March 1896, another projector of Paul's was installed at the London Olympia, and still another renamed the Animatographe, was installed at the Alhambra Theater in Leicester Square, London, March 25th, 1896. The original agreement was for a two weeks engagement, but the projector remained as part of the Alhambra performance for upwards of two years.

Paul, however, cannot lay claim to be the first to in-

stall and show projected pictures in a London theater, because in February 1896, about a month earlier than the Paul theater premier, Lumiere of Paris, had brought over his Cinematographe and had opened at the Polytechnic in Regent Street.

In 1897 Paul developed a four-star maltese cross intermittent projector, and added several fire prevention devices to the projector, these fire prevention devices being prompted by the fact that some 73 persons had then just recently lost their lives in a film fire in Paris.

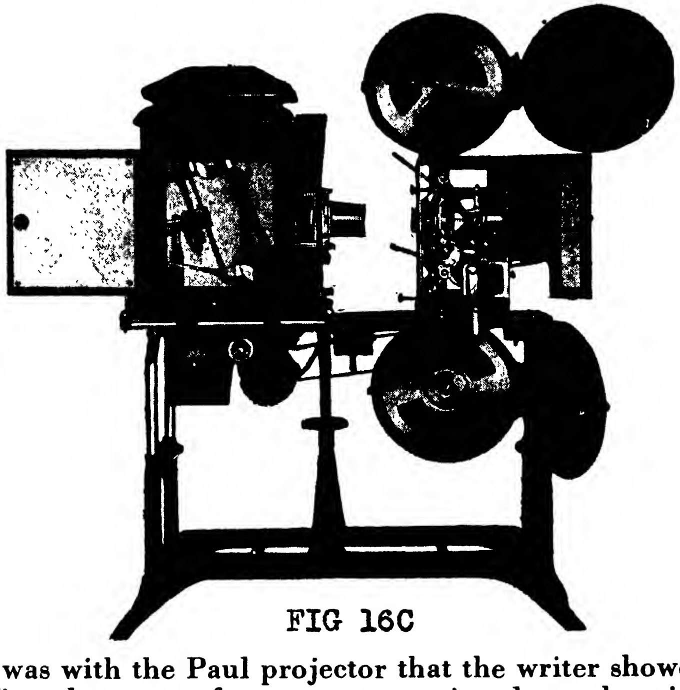


FIG 16C

It was with the Paul projector that the writer showed his first theater performance, some time later changing this for a Prestwich Projector with a dog beater intermittent movement, the light source being obtained from two cylinders of gas and a "lime pin."

It has thus been shown that working independently of each other, each keeping their activities as much of a secret as possible, Armat, Latham, Paul and Lumiere were all working along similar lines to produce a ma-

chine commercially capable of projecting pictures in motion, it has been shown that all of the early inventors, were prompted in their efforts by first contacting in some way the Edison Kinetoscope peep-hole machine.

With motion pictures now commercially possible, it seemed that every mechanic with access to a machine shop wanted to go into production, producing projectors. A number of attachments, much like the first Paul

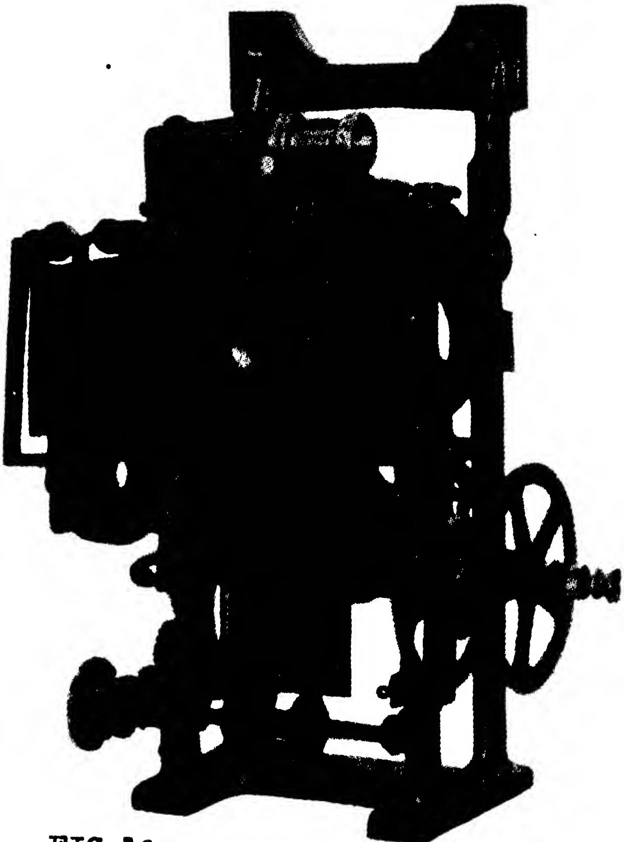
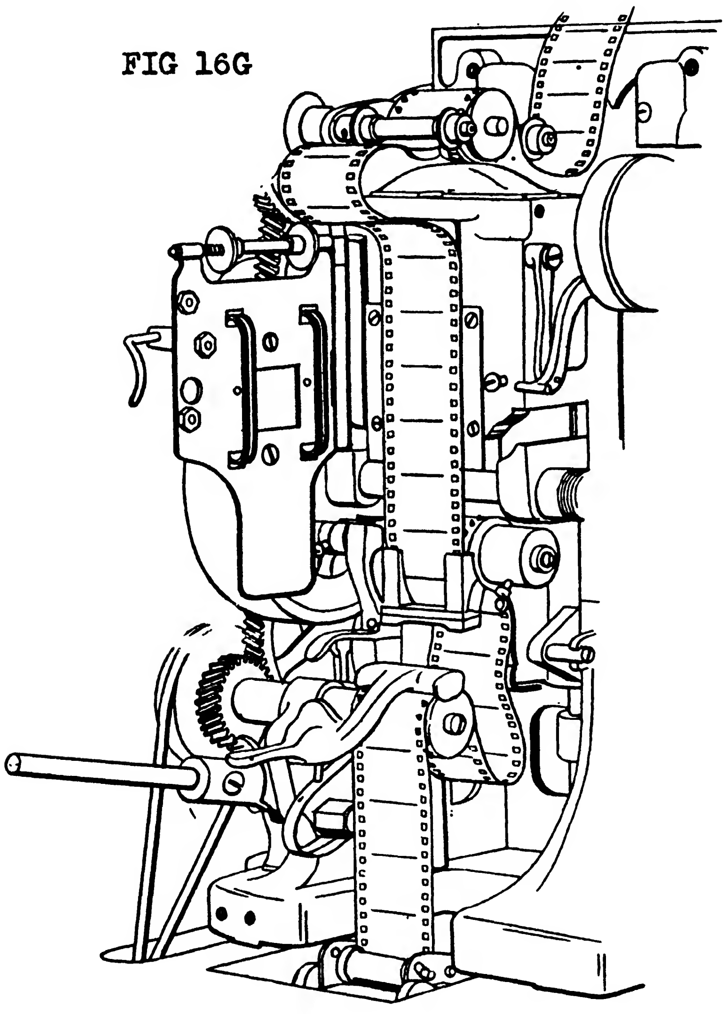


FIG 16D

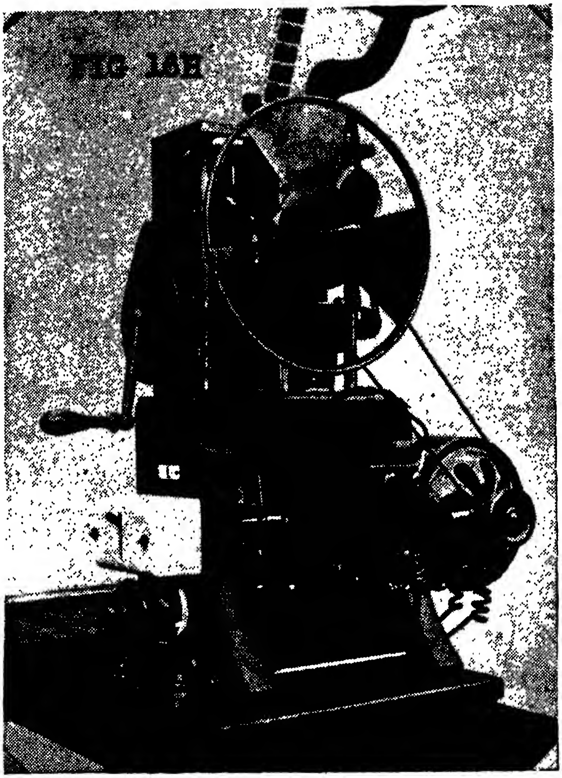
projector were made both in this country and abroad, these had to be used with existing steropticons, the Riley Brothers, of Bradford, Yorks, England turned

out the Kinetoscope, this employed a "claw" intermittent. Eberhardt Schneider of New York, built the Wonderscope and was used by him at the Empire Theater in Brooklyn, N. Y., in 1896. The Kinetograph was patented in October 1896 by Newman and Guardia. The Magniscope another projector using a "claw" intermittent was introduced by Amet (not Armat) in

FIG 16G



1897, the same year the Veriscope was installed in the Academy of Music, in 14th Street, New York City, to show the Fitzsimmons-Corbett fight pictures, taken at Carson City, Nevada, in March 1897. This projector was also used as a camera to take the fight pictures. Then came the Biograph projector made by the Mutograph Corp., the Projectograph made by E. Kuhn, and sold through the old International Film Company,



Early in 1897 Edison's Kinetoscope (projector) appeared, this was one of the early projectors that remained in favor with operators over a period of years. Although Edison had been the first to see the possibilities of motion pictures, and had given the impulse to his followers, it was only to be a few years before

Edison dropped out of the picture both as a producer of films and a builder of motion picture equipment. Fig. 14A shows an early Edison Kinetoscope Projector.

In 1899 F. B. Cannock then an operator at the Eden Musee in 34th Street, New York City, developed a projector known as the Edengraph, after the place in which he worked, later when Cannock and E. S. Porter worked together, they re-built this projector and it eventually became the forerunner of the line of Simplex projectors in use throughout the world today.

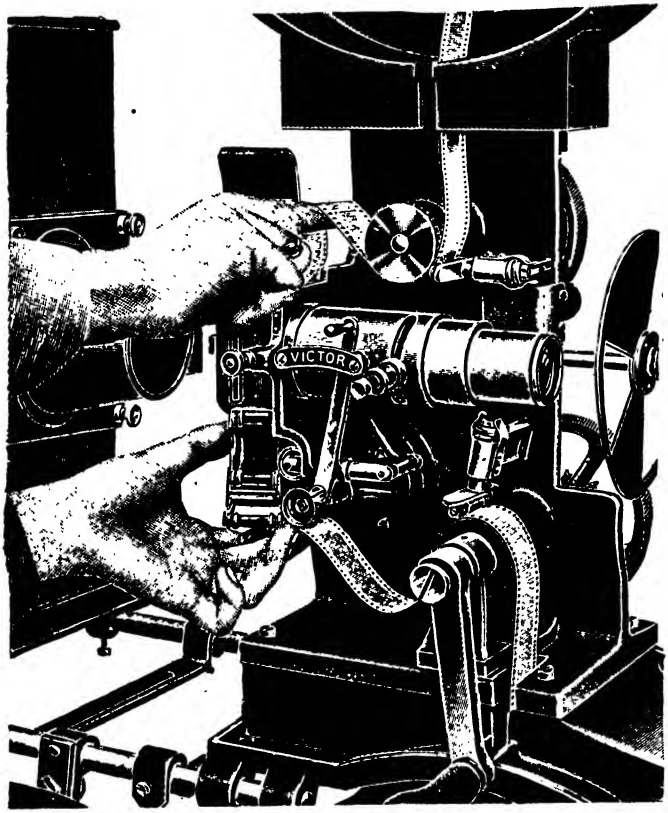
Another operator while working at the Eden Musee built a projector which he named the Micagraph, this operator Mike Berkowitz, still carries an I. A. card and works as projectionist out of the New York Local.

We could go on and on filling page after page with the "graphs" and "scopes" that were turned out by every little machine shop over this period. This writer who made his living during these years as an "operator", seldom when changing jobs, found the same make projector in any two theatres, and can well remember his amazement when called to a theatre in Brooklyn, N. Y., to find he was to operate a "Cameron" projector. Which we later learned was manufactured in Brooklyn.

The manufacturing of projectors became a "business" with the advent of the Nichols Powers Company, the Precision Machine Co., manufacturers of the Simplex, and the Optical Enterprise Company. The two former are now jointly known as the International Projector Corp. The "inside" story of the fight put up by these manufacturers in the early days is full of drama. That these concerns overcame what seemed like unsurmountable obstacles and difficulties, spending both time and money in research to perfect the projectors as we know them today, stands as a testimonial to American progressiveness.

Credit should also be given to the Society of Motion Picture Engineers for the great part played in securing the adoption of motion picture standards covering projectors and projecting equipment, and lastly full credit should be given those "old timers", those operators who

through their practical experience and close cooperation with the manufacturers and later with the S.M.P.E. through the Projection Practice Committee headed by Harry Rubin, wholeheartedly gave of their time and labors that theory and practice could find a common working ground.



PERSISTENCE OF VISION

A very important phase of the research for perfecting the true representation of nature was to discover the means by which *motion* could be imparted to pictures.

The reproduction of motion is an accomplished fact, brought to a degree of perfection seldom equaled by any other discovery in the short lapse of time since its discovery.

Analysis and synthesis are the means by which the reproduction of motion is obtained, as they are the underlying factors upon which modern color photography is dependent.

Analysis by the resolution of movement into a series of secondary movements constituting a given whole is accomplished by photographic means, and synthesis by putting together the secondary movements thus obtained to form the whole desired movement, by means of projection.

This description of the essentials of moving pictures may seem rather abstruse but can be readily visualized.

Imagine the moving of an arm from a dangling position to an upraised one and consider this movement from the initial to the final position, as a *whole movement.* We can easily visualize innumerable intermediary positions that the arm is to pass through to reach the final one. As the whole movement of the arm is logically a continuous one the number of intermediate positions is infinite.

The problem that was faced by the researcher on the subject, was to find out how many of these intermediate positions were to be photographically registered, so that when viewed in rapid succession they would give to the eye the impression of continuous movement.

A well-known physiological phenomenon known as *the persistence of vision,* gave the answer.

When the light emanated by an object enters the eye an image is formed on the *retina,* which is a membrane of the eye that can be compared to the sensitive plate receiving the image formed by the camera obscura.

This retinal image has a certain permanency. It lasts for a short while before being cancelled by the succeeding image or by its natural elimination proper to the functioning of the eye.

This permanency or persistence of vision depends partly upon the intensity of the light that concurs to form the image, partly upon the intensity and character of the image that is going to supersede it.

Many are the examples that can be cited to illustrate the phenomenon of persistence of vision.

Falling drops of water look like uninterrupted water threads. In a rapidly rotated wheel, its spokes cannot be seen: but if the wheel is rotated in darkness and intermittently illuminated by sudden flashes of light, by means of a rapid succession of electric sparks, for instance, the spokes may be clearly made out. If a red hot piece of charcoal is rapidly moved about we see continuous streaks of light marking the displacements of the charcoal.

An amusing incident is often related on this subject.

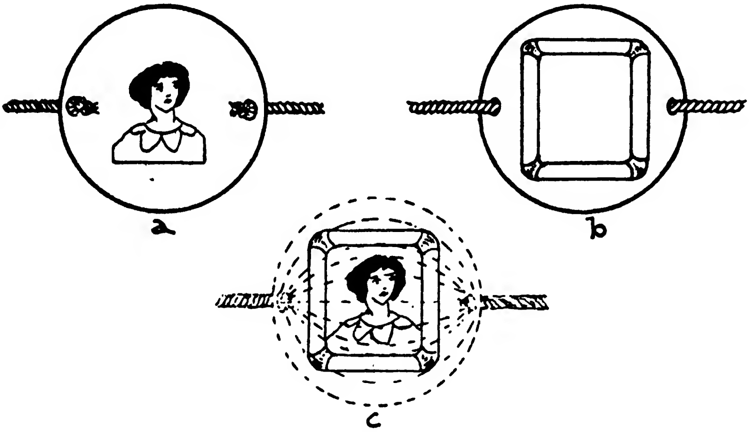
In 1825, during an after dinner conversation, at which the eminent physicist Sir John Herschell was present, to amuse the gathering, Herschell asked if anyone in the audience could demonstrate how both faces of a coin could be seen at one time.

Someone suggested the holding of the coin in front of a mirror, but Herschell showed that the trick was possible by spinning the coin at a certain speed. Through the phenomenon of persistence of vision one face on the coin would make an impression on the retina of the observer before the impression of the other face had completely vanished.

This experiment led Doctor Finton, the following year, to construct a little, simple toy consisting of a

round card on one face of which a cage was drawn and on the other face a bird. By spinning the card on its axis the effect was obtained that the bird appeared to be in the cage. This instrument was called the "*Thaum-athrope.*"

Quite recently jewelry trinkets were in demand consisting of a gold disc on one face of which portions of a word or phrase were engraved and the remaining portion of the same word or phrase was also engraved on the other face. The disc was so mounted that it could easily be spun and by doing so the whole word or phrase could be read in its entirety.



Although the phenomenon was mentioned by Leonardo da Vinci, in 1472, it is quite impossible to fix with exactness the very beginning of the application of the persistence of vision to practical experiments or instruments. It is an historical fact that Newton, about the year 1670, proved his theory on the composition of light by pasting strips of paper of the colors of the spectrum on a cardboard disc, the dimensions and positions representing five spectra covering the whole surface of the disc. By rotating the disc by mechanical means the different colors blend and a uniform tint can be seen which changes according to the speed of rotation of the disc. When the disc is rotated at a certain

high velocity the disc appears white thus proving that white light is formed by the fusion of all the colored lights of the spectrum.

Newton's disc proved the physiological fact that the impression on the retina always last longer than the stimulus (source of light) and that if a new impression is allowed to be formed before the previous is completely extinguished an impression consisting of the blending of the two is obtained and, furthermore, that several impressions can be made to react simultaneously on the retina. In the case of Newton's disc the seven colors of the spectrum, multiplied by five, represented thirty-five stimuli making an impression on the retina simultaneously.

Plateau, in 1849, investigated the duration of the persistence of vision and although, as previously stated, it varies according to the intensity of the stimulus and to the sensitiveness of the retina, he placed it at as long as 30 seconds, as an average.

Further investigation proved that the impression on the retina is not immediate; it gradually increases until it reaches a maximum and then gradually decreases to disappearance, so when stimuli are made to react on the retina even in rapid succession, they quite harmoniously blend into each other.

The action of the retina is nevertheless extremely rapid and the normal eye can perceive a flash of light, such as an electric spark, having a duration of only 1/8,000,000 of a second. In such short duration the impression is not brought to the maximum ability of the retina to collect it, so that a light of low intensity, but long duration, makes a greater impression on the retina than a light of higher intensity but of extremely short duration.

In all apparatus dependent upon the phenomenon of persistence of vision the length of the stimulus must be sufficient to make its full impression on the retina and the intermittences must be of a duration sufficiently short to overlap the gradual decrease of the first with the increase of the second.

It has been established that the most efficient duration of the stimulus in the presentation of motion pictures with the average light intensity of the projection arc is of approximately 1/50 of a second with an equal interval of darkness. (Frequency 50.)

PERSISTANCE OF OPTICAL IMAGINATION

For years this theory of persistance of vision has been taken for granted by workers in the industry, and has served to account for the illusion of motion on the motion picture screen, it was left to Terry Ramsaye, in his book A Million and One Nights, to advance the theory which he termed "persistance of optical imagination" and we are giving you his word for word argument in favor of his theory, this being taken from his book, and for which full credit is hereby made.

"Ever since the first attainment of the projected film picture the simple statement of the principle of "persistance of vision" has been accepted generally as the complete explanation of the motion picture. That is too simple and easy to be true. After all, seeing a motion picture is something more and rather different from just piling one optical impression on top of another in the eye. True persistance of vision, or the holding of an image in the mind's eye until the next arrived to take its place, would result more likely in a jar between the successive phases of motion presented by the screen record. In rapid motions which are well portrayed on the screen this jar would be considerable."

"Following the researches of the experimental psychologists we must admit that the eye can only see what is there to be seen, namely a series of still pictures. The mind does not rest. By simile we may say that the screen shows the eye a row of dots and that the visual imagination makes a continuous line of it. We often, elsewhere than the screen, think we see motion where none exists. There assuredly is no motion on the screen."

"The successive still pictures of the object in motion appear merely to supply cues to an altogether mental process by which we build our impression of seeing it move. It would seem that there is something in our experience of seeing actual objects in actual motion which helps us to see movies, always in a forward direction. An exception to this progressively forward impression occurs in the common screen phenomenon of the wagon wheels which turn backward as the vehicle goes forward. On the strict theory of persistence of vision this would be impossible. It is possible only because the spokes are to the eye exactly alike and we can mistake a spoke behind in the progression of the wheel for the one we saw ahead. In other words, our mind gets a miscue because of the failure of the eye to identify. If our eye were so faulty as to confuse two actors we might get even more exciting results, but they would be of the same category."

"It is significant here that there is some evidence that we do not all see the motion picture alike. It was a common experience, when motion pictures were less common, to undergo a process of acquiring the conventions of screen seeing. The screen unquestionably offers a much more complete optical illusion to those who have grown accustomed to reading it.

"Let us analytically consider one foot of motion picture film, occupying one second of screen time in the theater (the 16 frames, one foot per second rate is based on the old silent picture rate), and calculate just how little the eye can actually see. It will give us a clearer notion of what a will-o'-wisp this motion picture illusion is. In exposing the negative for that foot of film in the camera, sixteen seperate and distinct individual pictures or snapshots of the subject are made. Under full illumination with the camera shutter aperture cut down, just as the amateur photographer speeds up the shutter in his Kodak to reduce light, these sixteen little snapshots may be exposed as briefly as one five-hundredth part of the second. This is a medium figure, exposures as brief as a five-thousandth

of a second are possible if the light is strong enough. Now with the exposure one-five-hundreth part of a second our camera's eye is open to take note of the happenings before it, for only sixteen five-hundredths of the time our foot of film is travelling through the camera. This is a total of .032 of the total time."

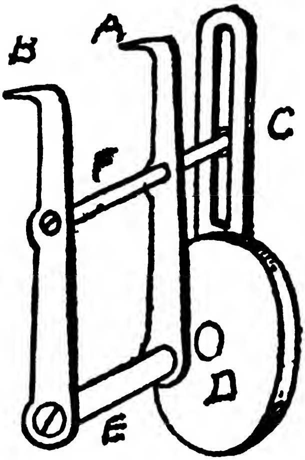


Fig. 17

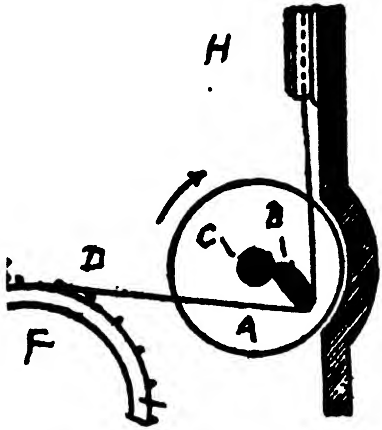


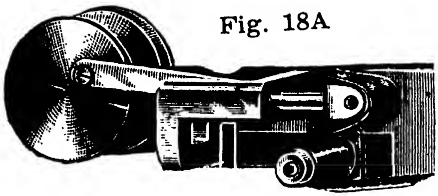
Fig. 17A

"The camera makes note of what happens in sixteen instances of a five-hundredths of a second each. The camera is not recording what is happening approximately 97 per cent of the time. Yet when a positive print from the negative is presented in one second on the screen the spectator thinks that he sees what is going on continuously, all of the time. The spectator is only three per cent correct. It is not what we see but what we think we see that makes the picture. Pure persistence of vision does not explain that. Persistence of optical imagination is nearer the fact."

"It is interesting to reflect that assuming the same rate of exposure, one five-hundredth part of a second per frame of the film, a whole battery of cameras, say fifty, could be set up side by side to picture the same

event in the same time and make as many entirely different records of it. If each camera was timed to expose in succession after its neighbor down the row, there would result fifty negatives, no two of which would be technically and literally alike. A foot of film from each camera would contain its sixteen snapshots made in a different series of five-hundredths part of the same second of time. All fifty negatives would be different, each from the other. Even more amazing, all of the total of eight hundred exposures included in the fifty.one-foot negatives made in that one second would be different."

Fig. 18A



"Yet when each of these fifty pictures were projected on the screen they would all tell the minds of the audience the same story. No human eye could tell one picture from the other on the screen. The mind can put together eye-reported fragments amounting to three per cent and derive from that a sensation of seeing 100 per cent. The old saw about "putting two and two together" concerns a feat really trivial by comparison. We evidently believe a great deal more than we see. The eye reports facts but we see fancies."

INTERMITTENT MOVEMENTS

A reading of the first chapter has made us more or less familiar with the various types of movements employed in projectors to impart the intermittent motion to the film in its travel past the gate aperture, the chapter on Persistence of Vision has shown us why this intermittent motion is necessary. Let us now briefly study the different types of intermittents and their construction.

CLAW MOVEMENTS

This movement is sometimes referred to as a pin movement. It is used today mostly in cameras and in several makes of 16 mm. projectors. This is the type of intermittent movement first employed by Lumiere. The movement was used in a number of projectors especially of foreign manufacture until the outbreak of the first world war, it has now been replaced in modern 35 mm. projectors by other type movements.

In the claw movement, the film is moved by two claws, or pins engaging in the film perforations. The claws obtain the up and down movement from an eccentrically pivoted crank, and gets the in-and-out- motion, from the action of a cam.

By referring to Fig 17 the action will be understood. In the diagram D is a constant revolving disc, while the projector is in operation. E is a shaft, which is fastened to the outside of this disc, near the rim, and is mounted at right angles to the disc. On this shaft, are mounted two uprights, seen in the diagram and marked B, and A, the ends of the shafts being shaped into claws.

Thus the continuously rotating disc D, will give a

reciprocating motion to the two claws. The in and out motion is obtained through the action of shaft F, being held in the slot C. From the diagram and description it can be seen that when the revolving disc turns in the direction shown by the arrow, the two claws will engage in the film perforations, each time they are pulled down. The claws being automatically freed from the perforations as the downward motion ceases, and they stay disengaged with the film as they make the upward trip.

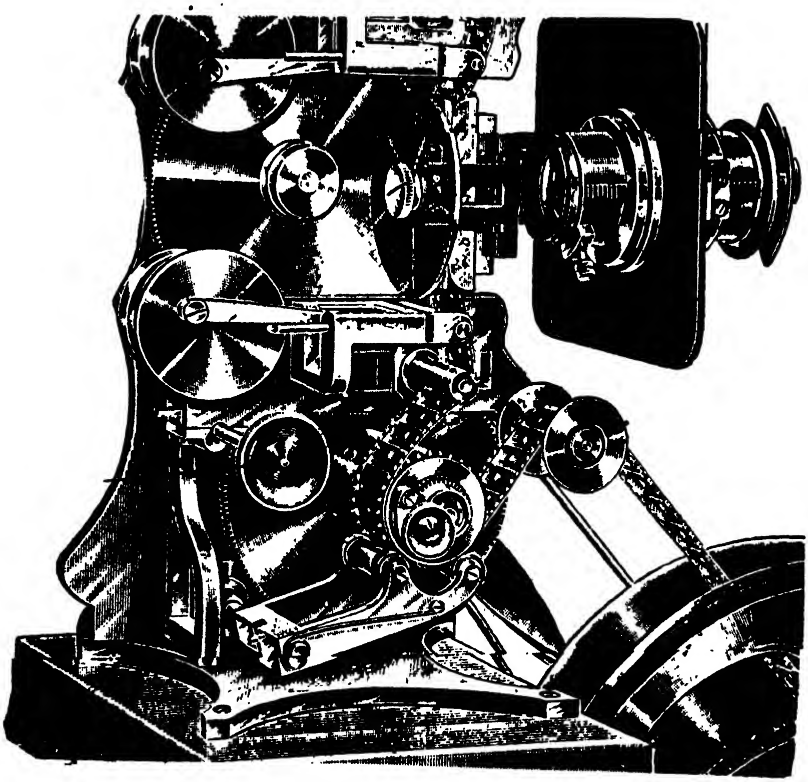


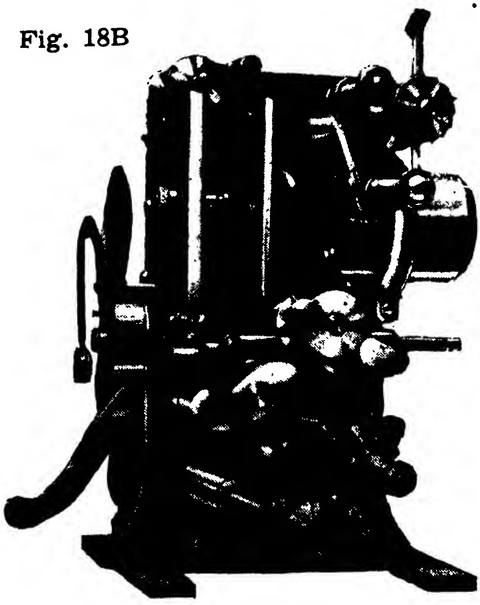
Fig. 18

BEATER OR DOG MOVEMENT

This is the type of intermittent movement first used by Armat and Jenkins, besides being the first type of

intermittent used on a projector it is also one of the simplest. The name Beater movement, describes its working principle, it moves the film, by a series of beats, each beat gauged to draw the film down the space of one frame. In using a beater movement, it is necessary to keep a rather tight tension on the film as it passes through the gate, so there will be no backlash on the film, which would show up on the screen in the shape of a jumpy picture. One of the faults of the beater movements is that it is verv noisy.

Fig. 18B



The working of the movement can be understood and followed by reference to the diagram Fig. 17A. A, B, C, is the intermittent movement, a disc on which the beater B, is mounted at right angles. H, represents the lower part of the projector gate, and F, the film running from the gate, via the beater movement to the take-up sprocket E. As can be seen in the diagram, the take-up sprocket runs in a counter-clockwise direction. As the beater movement turns, the pressure on the film at beater B, is released, the lower take-up

sprocket taking in this slack, by the time the beater has made practically one revolution, from the position in which it is shown in the diagram, it again engages the film and draws the slack film down the space of one frame, thus bringing the succeeding picture into alignment in the gate aperture.

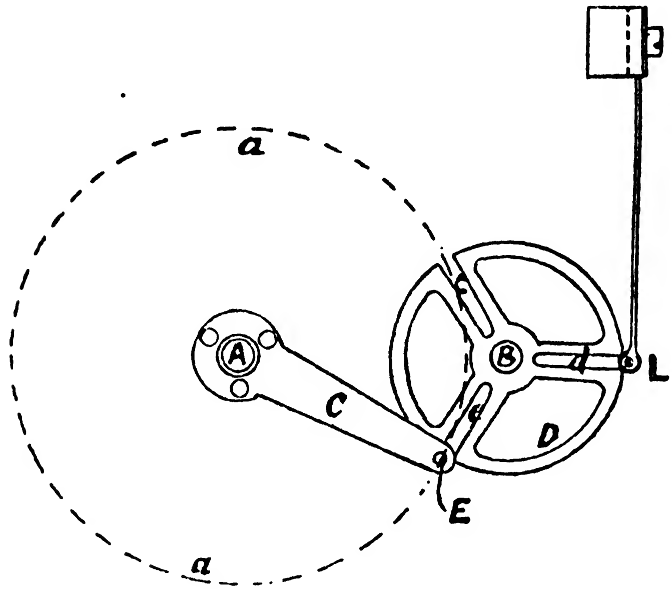


Fig. 19

Another type of the beater movement was used in the Hughes Projector, shown in Fig 18, a detail of the movement, known as the Piston Plunger Movement is shown in Fig 18A. As can be seen the plunger was used in place of the rotating beater, to draw the film down through the gate, each time the plunger contacted the film it moved the film the space of one single frame.

Fig 18B, shows the mechanism of a portable suitcase projector, introduced about 1919, the intermittent driving factor being a "rotary pressure" device, this of course was just another form of the beater movement.

GENEVA MALTESE CROSS MOVEMENT

This movement takes its name from the fact that the movement was first used in a Swiss watch, made in Geneva. There are a number of adaptations of this movement, in the first chapter we spoke of three point geneva movements used by Robert Paul, shown in Fig 19, five and seven-point movements as shown in Figs 11, 12, 12A, 13A and 13B. Most of the modern day 35 mm. projectors use the Geneva Maltese Cross type

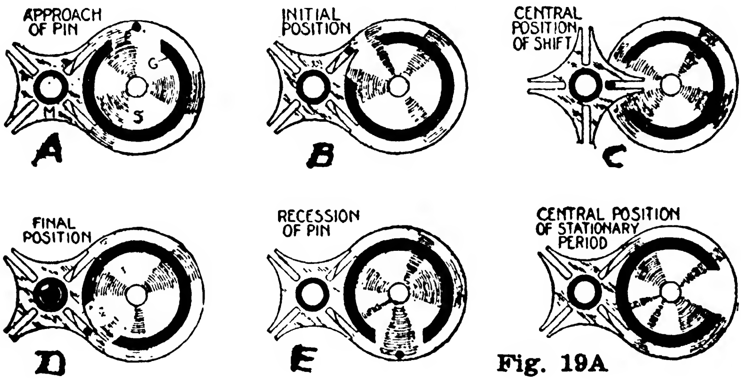


Fig. 19A

of movement in some form or another.

The diagram Fig 19A shows progressively the operation of the Geneva movement, a, shows the approach of the pin, b, the initial or beginning of the movement, c, mid-position of movement, d, final or end of movement, e, recession of pin, and f, mid-position of stationary period.

This Geneva movement, consists of a maltese cross, marked M, a disc, marked D, the disc being provided with a pin, marked F, and a circular guide, marked G.

In operation the pin disc S, is in continuous motion and the pin is so located that it enters one slot of the cross M, and carries it along with it, thus causing a one quarter revolution. The circular guide G, is cut away sufficiently to allow the cross to make a one quarter revolution, but when it registers with the cross it holds the latter securely until the pin rotates around

to the next slot. It will thus be seen that this action is very similar to that used in the old Paul projector.

Another movement of this type, one employed in the old Powers projectors, employed a cam and locking ring and a pin-cross with rollers. Fig 19B shows the location and the relative position of the units making

Fig. 20

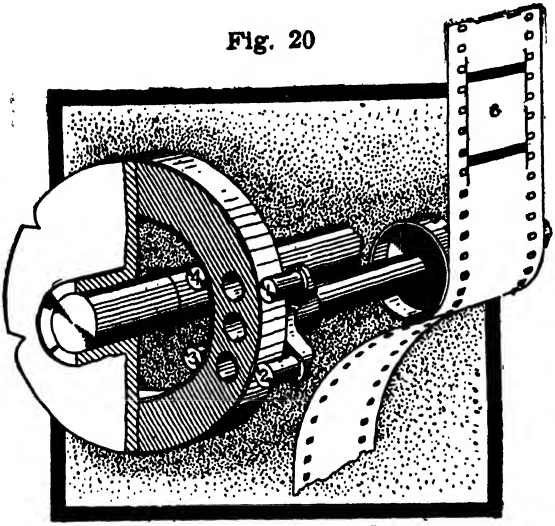
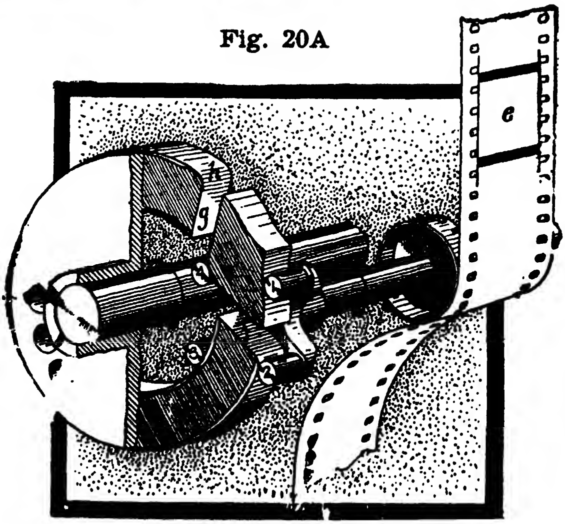


Fig. 20A



up the Powers intermittent.

The working principle of the movement can readily be understood by referring to the Figs 20, 20A, and 20B and 20C. In these drawings the back of the cam-ring disc has been cut away so as to expose the workings of the unit, during one revolution of the disc.

Fig. 20B

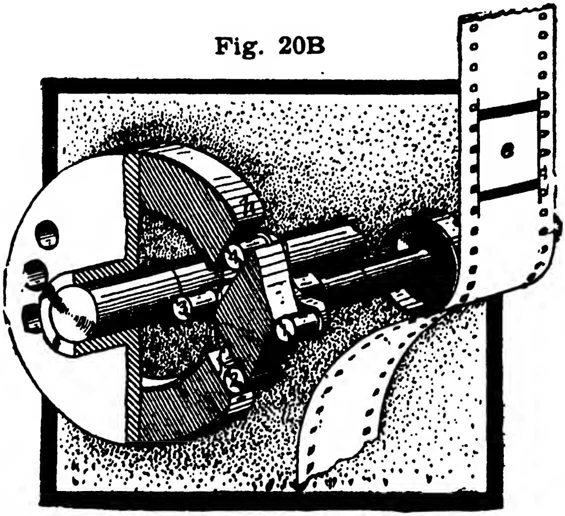
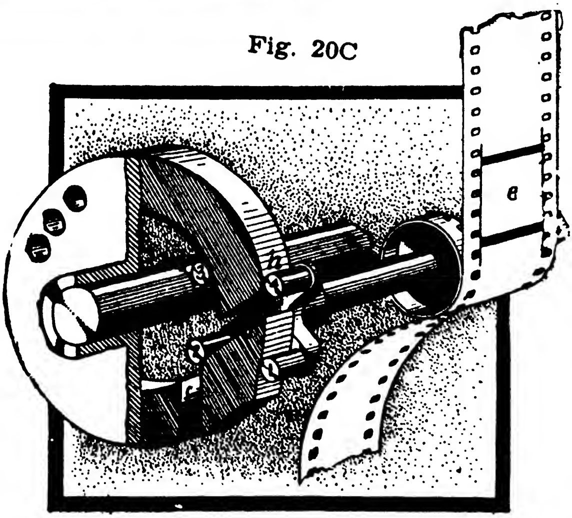


Fig. 20C



The curved arrow shows the direction in which the parts are revolving. The sprocket is in mesh with a short length of film. Portion of this film which lies between the heavy cross lines, represents one of the frames of pictures to be projected upon the screen.

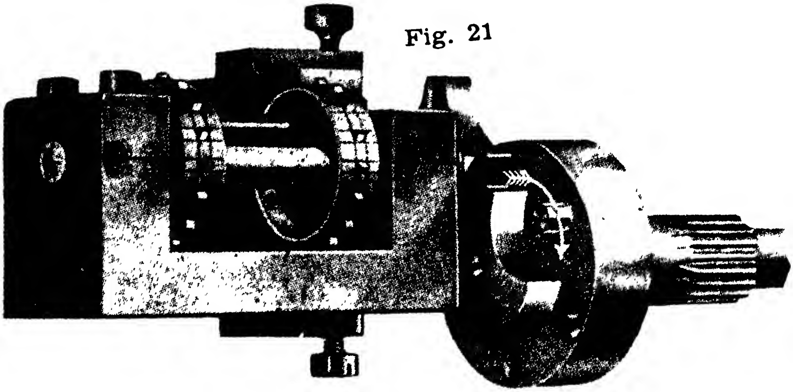


Fig. 21

In Fig 20, the four pins of the pin-cross are shown in engagement with the locking ring. Pins 1 and 2 are at the outer circumference, and pins 3 and 4 are at the inner circumference of the ring. Although the ring is revolving, it cannot impart motion to the pin-

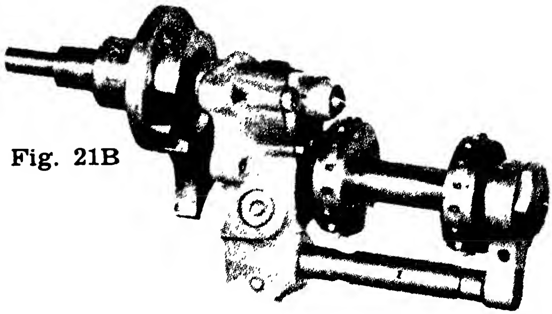


Fig. 21B

cross as the pins are securely locked by contact with inner and outer surfaces of the ring. Consequently the pin-cross, the sprocket and the film are all at rest. It is during this period of rest that the photographic view is being projected onto the screen.

In Fig 20A, the pins are disengaging from the locking ring, the cam is just starting to engage with pin 1. As the engagement takes place the pin is pushed forward and upward, thus imparting a rotary motion to the pin-cross spindle. The sprocket, being fastened to this spindle rotates with it, thus pulling the film downward.

In Fig 20B, pin 1, has almost reached the apex of

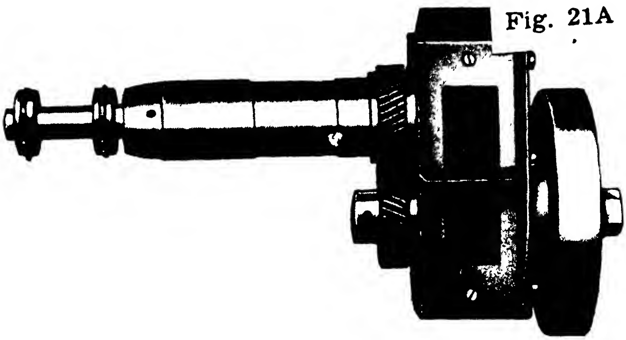


Fig. 21A

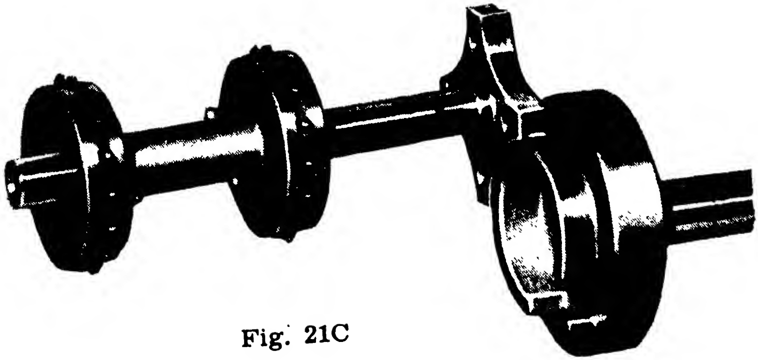
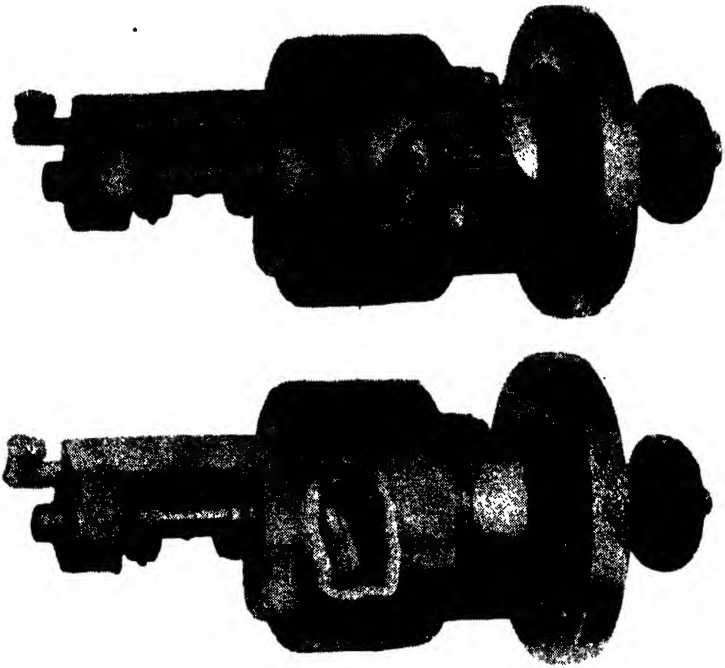


Fig. 21C

the cam, pin 2, is travelling into slot f, pin 3, is describing an arc in the space between the ends of the locking ring, and pin 4 is travelling out of slot g. As pin 1 slides over the apex of the cam, pin 4 engages with the curved surface h, at the end of the locking ring, and the pin is thrown forward and upward until it slides on to the outer surface of the locking ring.

In fig 20C, pin 4 has just reached the outer surface of the ring. The four pins are immediately locked as the locking ring travels into the space between them. In contrast to the pin position in Fig 20, pins 1 and 4 are now at the outer circumference and pins number 2 and 3 are at the inner circumference of the locking ring. It can readily be seen that the pin-cross spindle has made a quarter revolution and that view e, has been drawn downward a corresponding distance.



Cut-away views of intermittent movement.

These pins can only move in the path of a circle. As pins 2 and 4 travel through their respective slots it would appear to the uninitiated mind as though the pins must travel in a straight line. This is not the case however. The fact that the cam-ring disc is revolving, constantly changing the position of these slots so that their straight lines intersect the circular path of the pins at successively different points. The move-

ment was designed to move the film downward by starting the motion with a scarcely perceptible pull that steadily increases to the maximum as pin 1, Fig 20B, slides over the apex of the cam, after which it decreases in the same steady manner until the pins are locked by the ring and the film is again at rest.

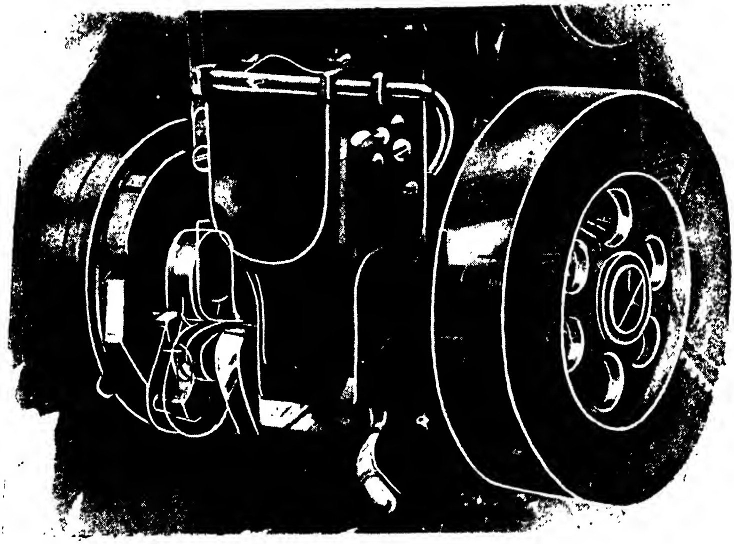
Fig. 21 shows the intermittent assembly of the Guamont projector, Fig 21A the intermittent assembly of the English Kalee projector, Fig 21B, the intermittent used in the DeVry projector, while the Motiograph intermittent is shown in Fig 21C. The intermittent assembly of the Simplex E-7 projector is shown at Fig 22, while Fig 22A, shows the intermittent of one of the first movie projectors.

Fig. 22A

SPEED OF FILM MOVEMENT AT APERTURE

The time necessary to move the frame of film, and the time given for each frame exposure on the screen, varies in each projector and with the use of different

types of intermittents. Just what these respective times are, has long been a debatable point with members of the craft. Herb Griffin, Vice President of International Projector Corporation, and technical head of the organization, gives us a chart Fig 22B, and his version covering the time of intermittent of the Simplex projector.



The Simplex intermittent composed of the cam and pin and star wheel assembly, is a 90 degree movement. The film moves at 90 feet per minute, or 90 multiplied by 16 (number of frames per foot) equals 1440 frames per minute, or divided by 60 equals 24 frames per second. The cam and pin revolve 24 times per second, and at each revolution turn the star wheel 90 degrees, pulling the succeeding frame of picture into frame at aperture. Thus the cycle takes place in 1/24th of a second.

However, as the movement of the film takes place in only ¼th of the cycle, the 1/24th of a second must be divided by four, which equals 1/96th of a second: and the picture is stationary in front of the aperture for the rest of the cycle, which equals 3/96ths or

1/32nd of a second.

Regarding the period of exposure on the screen. All standard 35 mm projectors to-day are equipped with two-blade shutters, one of which cuts off the light from the screen during the period the film is being pulled into place at the aperture. This, as we have already seen, takes 1/96th of a second, and the normal exposure to the screen, therefore would be the same period of rest, vis., 1/32 of a second.

RELATIVE TIME AND TRAVEL OF INTERMITTENT MOVEMENT

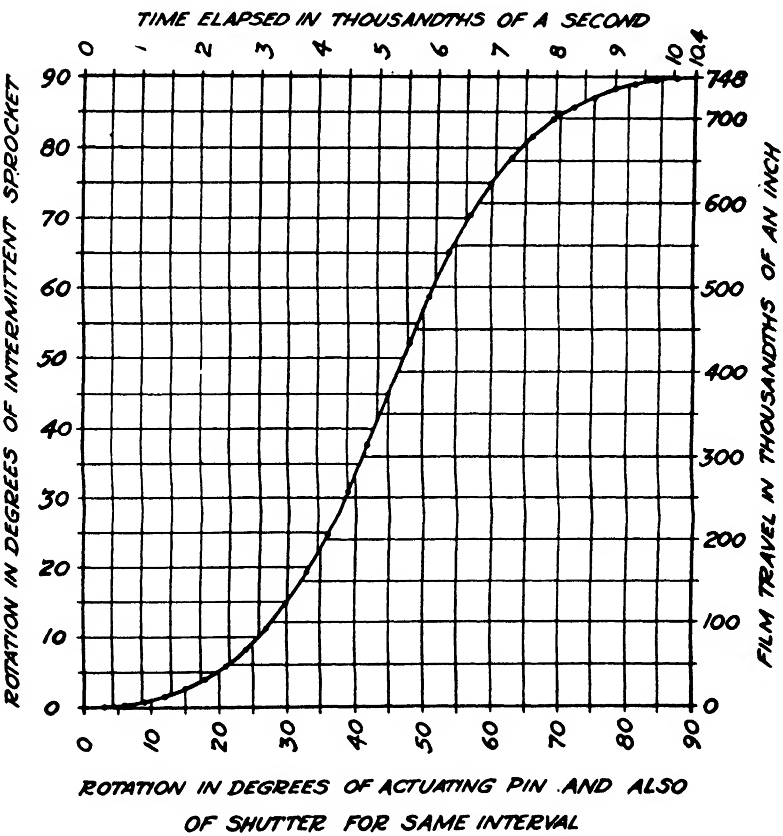
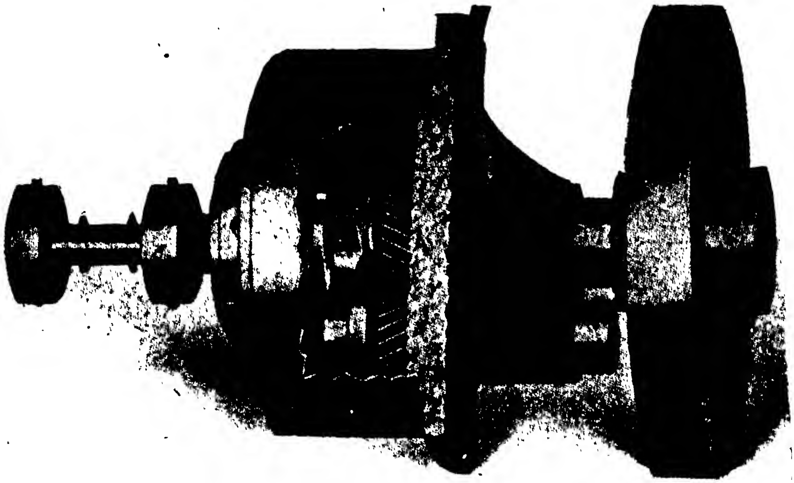


Fig. 22B

Since it is necessary however to introduce a second blade on the rotating shutter, this blade is known as the balancing blade, its purpose being to reduce flicker, and because this second blade is of equal dimensions to the light cut-off blade, another 1/96th of a second exposure is chopped off the screen, leaving only 2/96ths or 1/48th of a second as the final screen exposure for each frame of film.



These statements only hold good with a properly assembled and adjusted movement. The film during the first three degrees of the travel moves .0007", in six degrees .0028", and in nine degrees .0069", and comes to rest in approximately the same figures. The film is moving when the pin has entered the slot only three degrees, at a speed of 20 feet per minute, and it increases in speed up to 45 degrees approximately 870 feet, or 1/6th of a mile, a minute. It decelerates at the same speed.

In other words, the film speed at 45 degrees of the movement is about 43½ times faster than it is when the pin has entered three degrees. So for all practical purposes it can be assumed that the film is in motion for just about 1/96th of a second, and for just about 90 degrees of the movement.

ROTATING SHUTTERS

In the early Edison Kinetoscope peep-hole projector, no rotating shutter was employed, this was due to the fact that forty frames or seperate pictures were run past the viewing aperture every second. With the adoption of the 16 frames per second a light cut-off shutter became necessary. Some of the earliest projectors employed a single blade shutter, this was later supplanted by the two wing and then the three wing shutter. To-day practically all 35 mm projectors employ the two wing shutter. In passing we might state that the three wing shutter was invented in 1903 by Pross. The rotary shutter is positioned somewhere in the optical train and so adjusted that it will cut off the light from the screen, during that period of time in which the intermittent movement is bringing the film picture into frame at the aperture. The master or working blade, is of such a width that the film starts to move just before the light beam is cut off and this blade also starts to uncover the light beam just before the motion of the film is stopped. The working theory can be followed by referring to Fig. 23 and 23A, which shows a two-wing shutter.

Interruption of the light 24 times a second (24 frames of film pass the aperture a second in sound picture projection, as against 16 frames a second in the days of the silent picture) would result in pronounced flicker on the screen, so a second blade called the balancing blade, is introduced, to help balance the dark and light periods on the screen. In using two wing shutters these blades are generally made the same size. Where a three blade shutter is employed, the

master or cutting blade is larger than the other two.

Rotary shutters have a transmission of about 50 to 55 per cent for the two-blade, and about 40 to 45 per cent for the three-blade. So approximately 50 per cent of light from the arc is cut and wasted by employing a shutter.

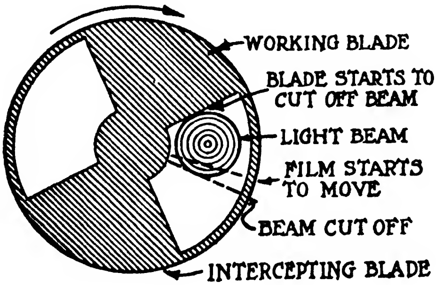
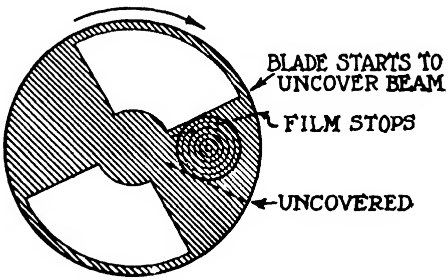


Fig. 23

Fig. 23A



In most of the early projectors, the shutter, generally a single blade, was positioned somewhere inside the mechanism, often immediately in front of the gate aperture (the side nearest screen), later these shutters were placed immediately in front of the objective lens, as shown in Fig. 23B, in modern projectors, the shutters, now greatly grown in overall size, are positioned between the source of light and the film. In this position they not only act as a light cutting agent but also greatly reduce the amount of heat that reaches the film

in gate aperture, from the arc lamp or other source of light. These shutters are known as rear shutters and an illustration of the one used by Simplex is shown in Fig. 23C.

Several of the latest projectors use both a front and a rear rotating shutter, these are interlocked, each operating on its own half of the light beam, see Figs. 23D and 23E, the light cutting action can be understood by referring to Fig. 23E. The objective lens be-

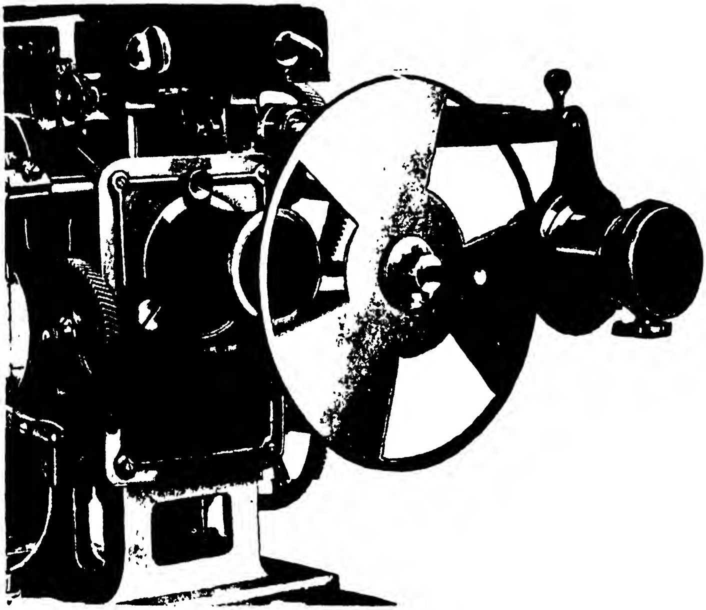


Fig. 23B

ing located between the two shutters, permits a narrower cut-off blade, a reduction from the usual 90 degree to about a 72 degree, giving a net gain in light transmission of about 12½ per cent.

Another type of shutter is the Horizontal Cylinderical Shutter. This is the type used by Motiograph and the English built Kamm Projector. This design of

shutter also permits a double or simultaneous cut-off of the light beam from top to bottom, it also tends to create a diffusing or blending effect, as does the use of the combined front and rear shutters employed in the Simplex E-7. The Motiograph shutter is shown in Fig. 24A and 24B shows how the disolving effect is attained by the cutting of the light beam at top and bottom of the light beam.

Simplex disc type rear shutter

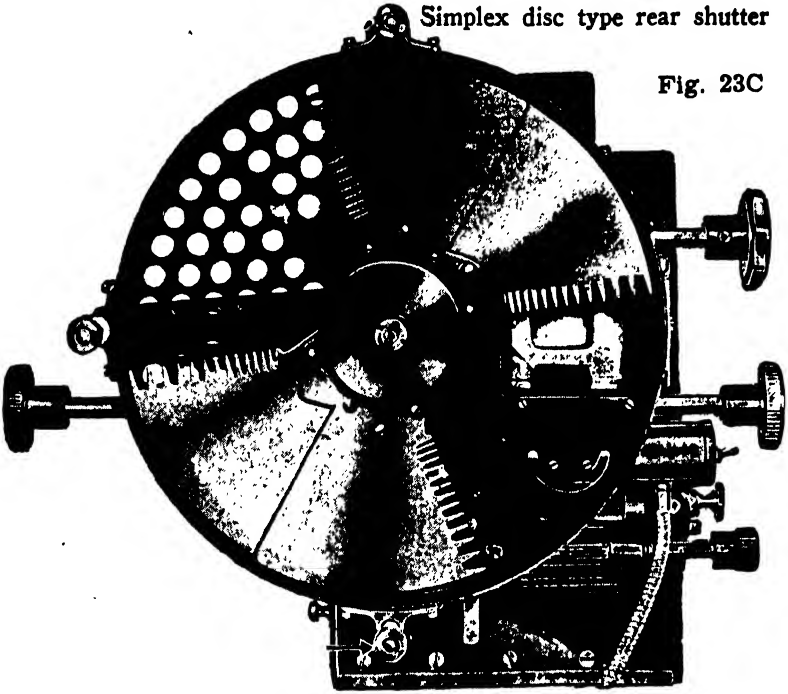
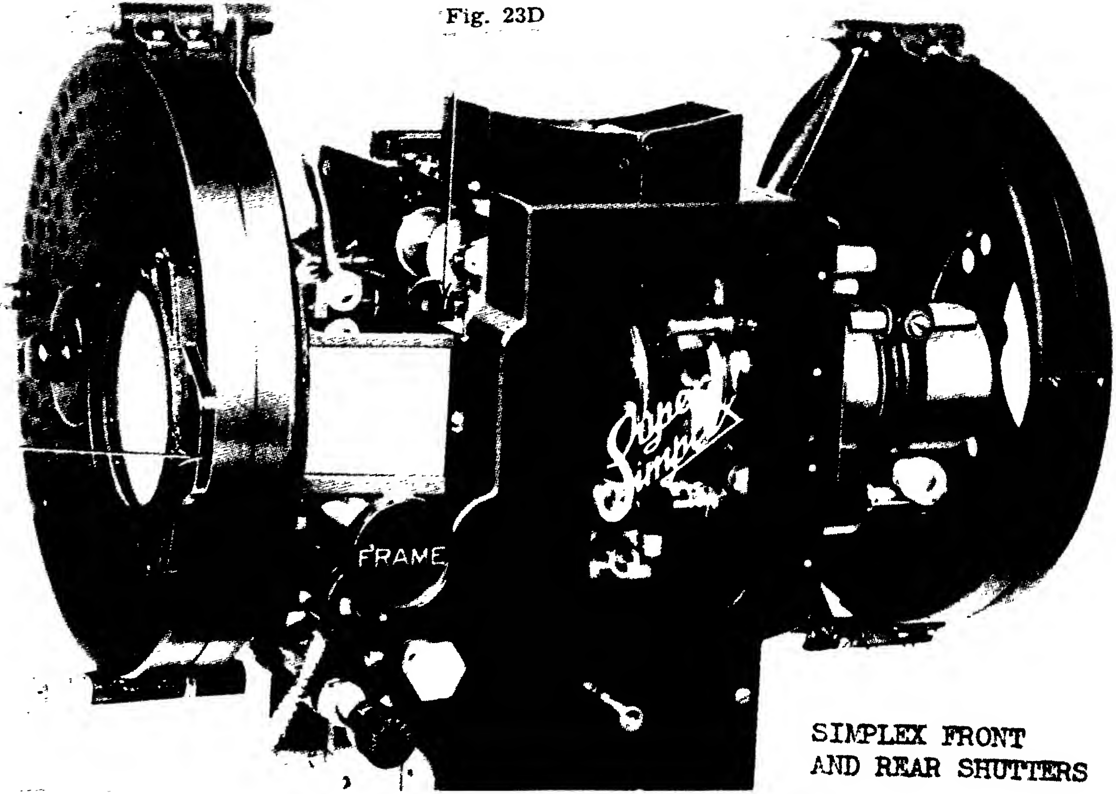


Fig. 23C

On most projectors to-day, some means is provided whereby the rotating shutter can be "timed" or "synchronized" while the projector is running. A simple adjustment to accomplish this is shown in Fig. 25,

The rotating shutter, no matter what its design or its position on the projector, has a definite working relationship with the intermittent movement, and no matter the number of blades, each shutter has only

Fig. 23D



SIMPLEX FRONT
AND REAR SHUTTERS

one "working" or "cutting" blade, this is known as the master blade, and it is this blade which is used in setting or timing the shutter.

This master blade is correctly timed when the course of its rotation brings the blade over the objective lens (or completely cuts the light beam) at the exact time that the intermittent starts its motion, and keeps the lens covered (or the light beam off the screen) until such time as the intermittent movement has again come to rest, and the succeeding frame of film has been "framed" in the gate aperture.

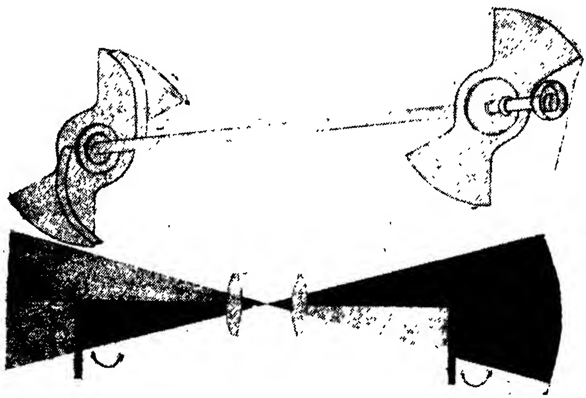
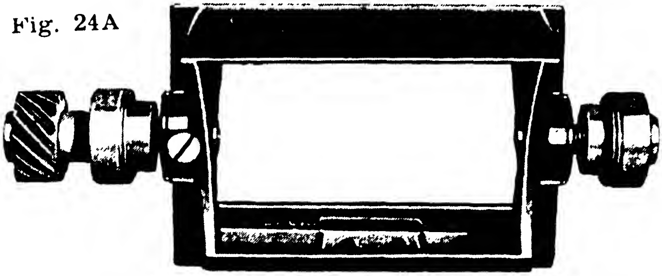


Fig. 23E Synchronized front and rear shutters.

Should the master blade cut the light beam too early or too late, white streaks, running up or down on the screen, will show in the projected picture. This is known as "travel ghost." The direction in which the white streaks seem to run, towards the top of the screen or towards the bottom of the screen, will depend on the shutter being timed either too early or too late. If timed too early, so that the blade passes the objective lens or the light beam, before the intermittent has come to rest, the streaks will appear to be running towards the top of the screen, as shown in Fig. 25D. If timed too late, where the intermittent starts its motion before the light is entirely cut off the screen, the streaks will

appear to be running towards the bottom of the screen as in Fig. 25E. Travel ghost may also be caused should

Fig. 24A



-Motiograph Horizontal type rear shutter.

the master blade of the rotating shutter be of insufficient width.

The timing of the rotating shutter is a simple operation, if one remembers that the working or master

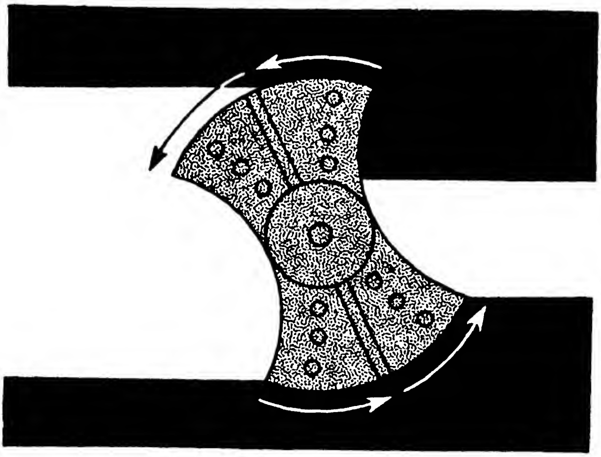


Fig. 24B

blade must cut off all light from the screen during the period of time the film is in motion in the gate of projector, or expressed another way, during the time the intermittent sprocket is in motion.

A quick and easy method, is to set the framing handle or adjustment in a midway position, turn the flywheel by hand, at the same time watching the intermittent sprocket, keep turning the flywheel slowly until the intermittent comes to rest, then place the thumb nail, or the edge of a small card, between any two sprocket teeth of the intermittent sprocket (two teeth on the same end of the sprocket), then again slowly turn the flywheel until two sprocket teeth have passed this given point. The master blade of the shutter should now be set so that the objective lens is in the dead center of the blade. It will of course, be necessary to first loosen

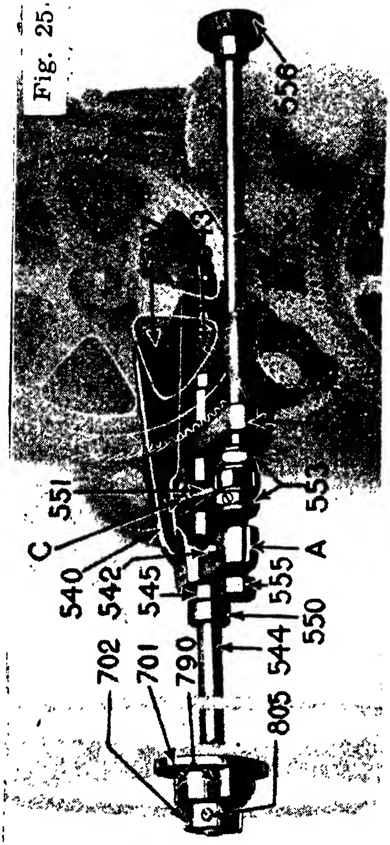


Fig. 25.

the rotating shutter from the shaft to which it is attached in making this adjustment. When correctly positioned the shutter should then be securely fastened to the shaft by means of the holding screws.

Another method is to lay a small flash light or incandescent lamp in the lamp house in such a position that the light rays may be seen by looking towards the lamp house through the objective lens. The fire shutter and any light-cut-off will have to be fastened up out of the way.

Thread the film through the gate of the projector. Slowly turn the flywheel by hand, all the time looking through the objective lens to the illuminated frame of film in the gate aperture, keep turning the flywheel until you feel the film in motion and until it again comes to rest. If the shutter is correctly timed, you will not be able to see the film in motion, the master blade having cut off your view during the period of time the intermittent movement was bringing the film down into place. Should the film movement be visible, either at the beginning or the end of the film movement, the shutter will have to be reset. If movement is seen at both the beginning and the end of the film movement, then the master blade is not wide enough or is not positioned correctly.

SETTING THE SIMPLEX E-7 SHUTTER

Setting the shutter is not difficult. A three-piece tool consisting of a barrel, a rod which has a flat face cut on each end, and a clip lever is furnished. To set the shutters: remove the lens and place the barrel in the lens holder.. Loosen the screws on the shutter knobs (which are now *outside* the guard). Remove the aperture and insert the rod through the barrel, lifting the fire shutter, and push the rod (flat face down) until the end comes through the shutter. Now clip the lever on the end of the intermittent shaft with the sprocket in the stop position.

Turn the shutter shaft by hand until the lever shows that the sprocket is at the starting point. Move the

cut-off blade of the shutter UP until it bears evenly on the flat face of the rod. Tighten the set screws on the shutter, and then going to the front shutter, follow the same procedure. Tighten shutter screws firmly. Now remove the rod, barrel and clip—and the job is complete.

TEST FOR SHUTTER EFFICIENCY

For the sake of reference let us assume that the following facts are familiar to most projectionists:

1. All shutters should have blades of equal width.

2. It is not necessary for the included-angle of the blades to be equal to the included-angle of the open spaces between the blades for direct current arcs. (With alternating current arcs, such as Cyclex, the included-angle of the blades must be 90° or greater.)

3. Flicker and travel ghost become more apparent as screen intensity is increased. (The exact intensity at which shutter flicker begins to appear is a difficult value to establish. An approximate figure for a 90° shutter is 9 to 10 foot-candles of light incident upon the screen, with 48 flashes of light per second passing through the optical system when viewed in a dark room. It is assumed that the reflecting efficiency of the screen is 75%, and that the projector is operated *without* film. This figure will vary slightly, depending upon the point of interception of the shutter.)

4. Shutter flicker becomes *less* apparent if the included-angle of each of the blades is *greater* or *less* than 90°.

5. If travel ghost appears simultaneously at the top and bottom of the picture image, the blades are of insufficient included-angle.

6. The film is in motion during 72° of each complete shutter revolution of 360°, or 1/5th of the time.

7. The speed of the optical system limits the width of the blades of the shutter.

8. The larger the diameter of the beam of light intercepted by the shutter the greater must be the included-angle of each blade.

9. A projector with a worn gear train requires shutter blades of greater included-angle than one with a new gear train.

10. The "covering angle," or number of degrees required for the shutter to cover the beam is controlled by three things: *First*, the distance from the center of the light beam to the center of the shutter shaft; *second*, the size of the light beam; *third*, the speed of the optical system producing the light beam.

11. The covering-angle, plus 72°, equals the maximum included-angle of each blade.

With the preceding review of well known facts before us, let us establish a basis for deciding which types of shutters are capable of efficiency tests and improvements, and which are not. In this discussion the various types and makes of shutters will not be compared in relation to the efficiency they bear to one another, as we are interested only in the efficiency of the equipment already in use.

Let us first identify all types of shutters which can*not* be altered in the projection room. Into this group fall all shutters of the compound type which intercept the beam simultaneously from opposite directions. This group includes the following make projectors: *Simplex E-7, Brenkert 80, Century CC, Motiograph K, HK and HU.* (Projectors having front or rear disc type shutters should be carefully checked for efficency.)

TRANSMISSION AND INTERRUPTION OF PROJECTION LIGHT

To demonstrate the effect of increasing the included-angle of the blades, *Table 1*, below, indicates the percentage of light transmitted and blocked by two blade shutters of the disc type.

These values remain unchanged, regardless of the diameter of the shutter, and are true for front or rear disc type shutters.

Because of this constant relationship between the included-angle of each blade of the shutter, and the

Number of Degrees of Included-Angle for Each Blade	Percent. of Light Blocked by Shutter	Percent. of Light Transmitted by Shutter
85	47.2	52.8
86	47.8	52.2
87	48.3	51.7
88	48.9	51.1
89	49.9	50.6
90	50.0	50.0
91	50.5	49.5
92	51.0	49.0
93	51.6	48.4
94	52.2	47.8
95	52.7	47.3
96	53.2	46.8
97	53.9	46.1
98	54.4	45.6
99	55.0	45.0
100	55.5	44.5
101	56.0	44.0
102	56.6	43.4
103	57.2	42.8
104	57.7	42.8
105	58.2	41.8
106	58.7	41.3
107	59.3	40.7
108	60.0	40.0
109	60.5	39.5
110	61.0	39.0
111	61.6	38.4
112	62.1	37.9
113	62.7	37.3
114	63.2	36.8
115	63.8	36.2
116	64.5	35.5
117	65.0	35.0
118	65.6	34.5
119	66.0	34.0
120	66.6	33.4
121	67.1	32.9

percentage of light transmitted, it is possible to determine the included-angle of each blade with a fair ac-

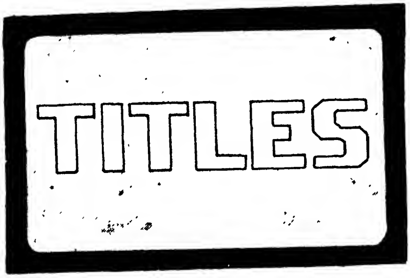


Fig. 25D

Fig. 25E

curacy in the following manner:

First. Take a reading with a photometer of the number of foot-candles of light incident upon the screen with the shutter in operation.

Second. Take a second reading from the same point with the light passing through the optical system without the shutter in operation.

Third. Divide the figures obtained in the first reading by those obtained in the second reading. The result is the percent of light transmitted by the shutter.

Fourth. Find this percentage in the column indicating light transmission in table already given. On the same line in the first column you will find the number of degrees of included-angle of each blade for the shutter you are testing.

For example, if the photometric reading for the first case with a shutter in operation was 13½ foot-candles, and the second reading taken without the shutter in

operation was 30 foot-candles, you would divide $13\frac{1}{2}$ x 30, which equals .45. The transmission would therefore be 45%. By referring to the table, we see that a shutter of 45% transmission capacity has an included-angle for each blade of 99 degrees.

REAR SHUTTER EFFICIENCY

The first consideration in rear shutter efficiency is the relationship between the optical speed of the reflector and the size of the beam of light which must be intercepted by the shutter.

If we assume conditions such as those found with standard Simplex projectors in which the rear shutter intercepts the light beam at a distance of approximately 5 inches from the aperture, and the center of the light beam is 3-15/16 inches from the center of the shutter shaft, it may be seen in Table 2 that a beam from an f/2.2 reflector has a diameter of approximately $3\frac{1}{8}$ inches, while a beam from a reflector set at an optical speed of f/3.0 has a diameter of only 2-9/16 inches.

Obviously, it requires a blade of greater included-angle to intercept the beam from an f/2.2 reflector than that required to intercept the beam from a reflector of f/3.0 optical speed.

To find the f-speed of any ellipsoidal reflector, measure the distance from the aperture to the reflecting surface at the center of the hole of the reflector. Next subtract the depth of the reflector from this working distance, and divide this result by the diameter of the reflecting surface.

Table 2 gives the approximate included-angle required for each blade of the rear shutter of a standard Simplex projector at various optical speeds, providing the screen is of average brightness. The column headed "Covering Angle" indicated the number of degrees that the shutter must travel to cover completely the light beam. In other words, this indicates the number of degrees the shutter moves from the time it just begins to intercept the beam until it has "sliced" com-

pletely through the beam.

In Table 2, the figures show

COLUMN 1—Approximate diameter of light beam in inches.

COLUMN 2—f-speed of reflector system.

COLUMN 3—Approximate covering angle for rear shutter located 5 inches from aperture with a distance of 3-15/16 inches from the center of the light beam to the center of the shutter shaft.

COLUMN 4—Approximate MAXIMUM included-angle for each blade.

COLUMN 5—Approximate MINIMUM included-angle for each blade.

TABLE TWO

1	2	3	4	5
2 9/16"	3.0	32° 30'	104° 30'	92° 30'
2 5/8"	2.9	33° 30'	105° 30'	93° 30'
2 3/4"	2.8	35°	107°	95°
2 13/16"	2.7	36°	108°	96°
2 7/8"	2.6	37°	109°	97°
2 15/16"	2.5	38°	110°	98°
3"	2.4	38° 30'	110° 30'	98° 30'
3 1/6"	2.3	39°	111°	99°
3 1/8"	2.2	40°	112°	100°

These figures are given in degrees of angle and minutes of angle. You would read the first figure in COLUMN 3 thus: 32 degrees, 30 minutes.

As every degree of angle is divided into 60 minutes, it follows that 45 minutes of angle is equal to 3/4 of one degree, 30 minutes equal 1/2 of one degree, 15 minutes equal 1/4 of one degree, etc.

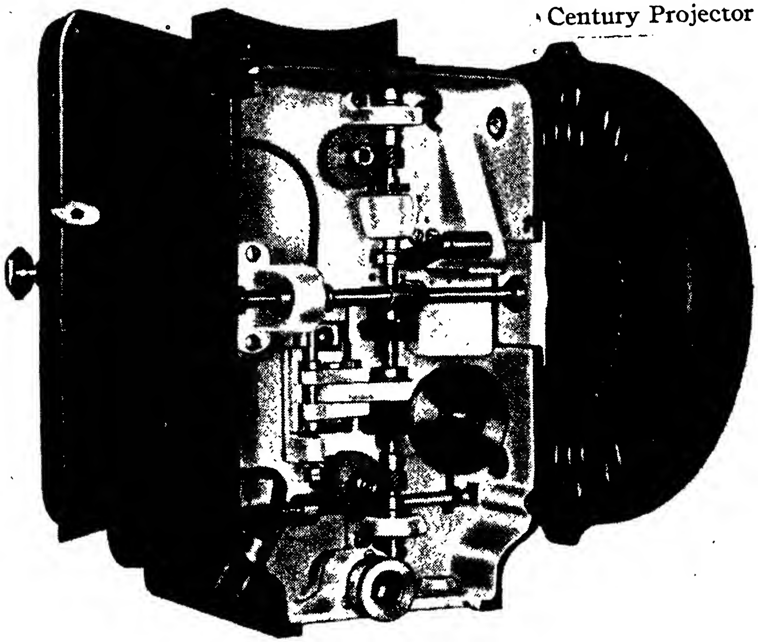
These figures are computed for average screen intensity. Lower screen intensity would permit blades of less included-angle, and higher screen intensity would require blades of greater included-angle.

The number of degrees of included-angle for each

blade of a disc type rear shutter will be between the *maximum* angle shown in Column 4, and the *minimum* angle shown in Column 5 of *Table 2.*

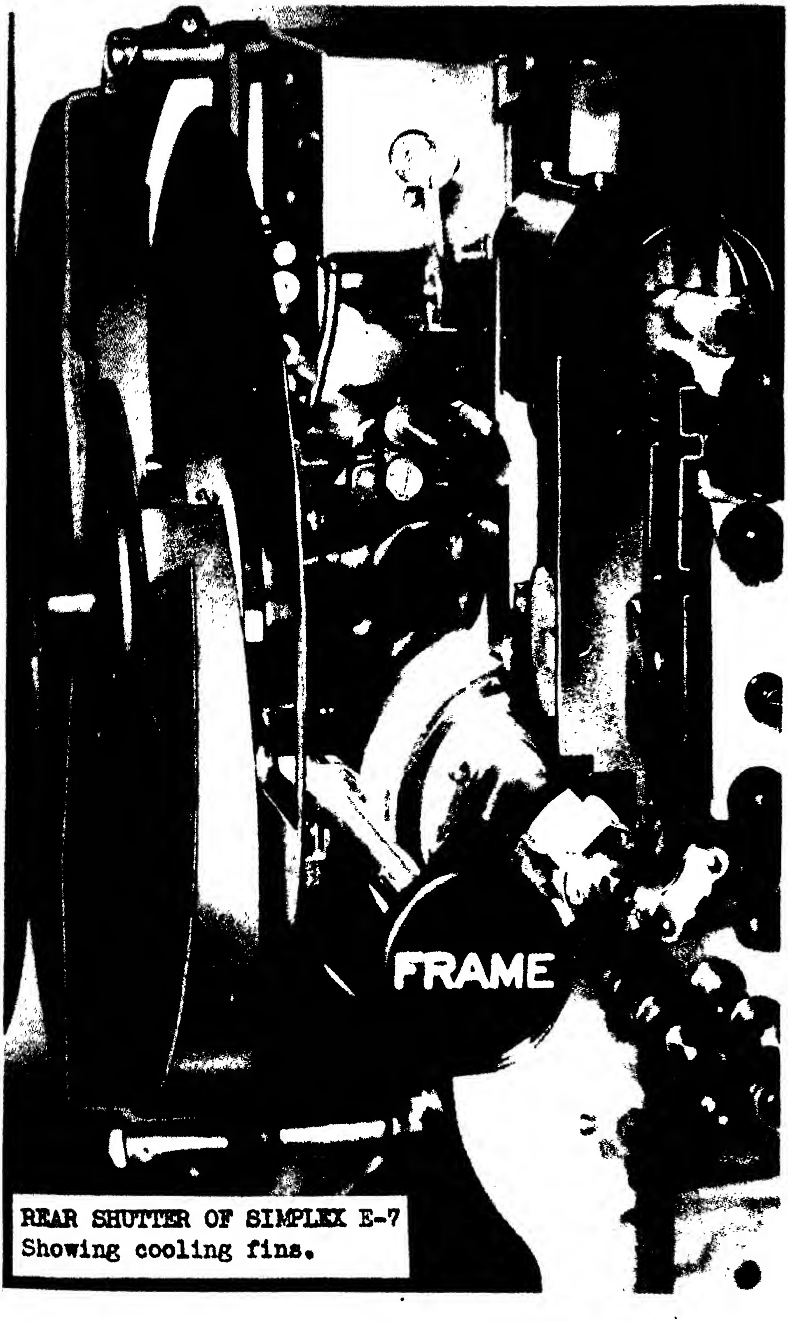
The number of degrees of angle between the figures given will depend upon the six following local conditions:

1. The intensity of the projected light.
2. The reflecting efficiency and type of screen.



Rear view of single-shutter mechanism.

3. The definition of the screen image.
4. The color of the light.
5. The amount of illumination used in the auditorium during projection.
6. The amount of lost motion in the projector gear train.



REAR SHUTTER OF SIMPLEX E-7
Showing cooling fins.

Because of number of combinations which can occur with these six conditions, it is necessary to determine the exact number of degrees of included angle for each blade by trial for each individual case.

To make this test, reduce the included-angle of each blade to the *minimum* shown in *Table 2*; and projecting a trailer or test reel of high contrast, observe for travel ghost. (This observation should be made from the front of the auditorium so that the observer is surrounded by conditions identical to those encountered by the patron.) If any ghost is visible, increase the included-angle a few degrees and repeat the test until all ghost disappears.

It is usually a very simple matter to change the included-angle of the blades of a rear shutter as most of them have an adjustment for this purpose. To make a direct measurement of the included-angle of any type disc shutter proceed as follows:

1. Remove the shutter from the projector and place it on a piece of paper.

2. Draw along the edge of each blade from the hub to the outside. (It is not necessary to draw around the curved part of the outer diameter.)

3. Remove the shutter from the paper and with a ruler continue the lines which could not be traced because of the hub. The point at which these lines cross is the center of the shutter.

4. Obtain a protractor with as large a radius as possible and place its center at the point where the continued lines cross.

5. Read the included angle on the scale of the protractor.

There are four conditions which are related to the included-angle of each blade of a disc type front shutter— *(1) optical speed of the projection system; (2) equivalent focus of the projection lens; (3) length of throw for any given projection lens E. F.; (4) position of the shutter in the beam of light.* The following rules govern these:

1. The *faster* the speed of the optical system the greater must be the included angle of each blade.

2. The *longer* the focal length or equivelent focus of the projection lens for any given fixed length of throw the greater must be the included angle of each blade.

3. The *shorter* the throw for a projection lens of fixed equivalent focus, the greater must be the included angle of each blade.

4. The *farther* the front shutter is plaeed in either direction from the point of aerial image, the greater must be the included angle of each blade.

Table 3 indicates the approximate number of degrees of included-angle required for each blade of a disc type front shutter, based on the beam diameter at the point of aerial image. It is assumed in this table that the front shutter is placed 3-5/16 inches from the center of the shutter shaft to the center of the light beam. The figures indicate:

COLUMN 1—Diameter of light beam in inches.

COLUMN 2—Approximate covering angle for a front shutter with a distance of 3-5/16 inches from the center of the shutter shaft to the center of the light beam.

COLUMN 3—Approximate MAXIMUM included-angle for each blade.

COLUMN 4 — Approximate MINIMUM included-angle for each blade.

TABLE THREE

1	2	3	4
1½"	25° 15'	97° 15'	85° 15'
1⅝"	27° 30'	99° 30'	87° 30'
1¾"	29° 30'	101° 30'	89° 30'
1⅞"	31° 30'	103° 30'	91° 30'
2"	33° 15'	105° 30'	93° 30'
2⅛"	35°	107°	95°

2¼"	37° 30'	109° 30'	97° 30'
2⅜"	39° 45'	111° 45'	99° 45'
2½"	41° 30'	113° 30'	101° 30'
2⅝"	43°	115°	103°
2¾"	45°	117°	105°
2⅞"	47°	119°	107°
3"	49°	121°	109°

It will be necessary to make the same tests as those described to determine the exact required angle between MAXIMUM and MINIMUM as for the rear shutter.

As the front shutter is not adjustable, it is suggested that experimental blades be constructed from cardboard for this test.

These tests are most important to obtain maximum results with minimum carbon and power consumption, and they are given in the hope that the simplified tables will induce the projectionist to test for, and correct, the unnecessary waste which results from improperly adjusted disc type shutters.

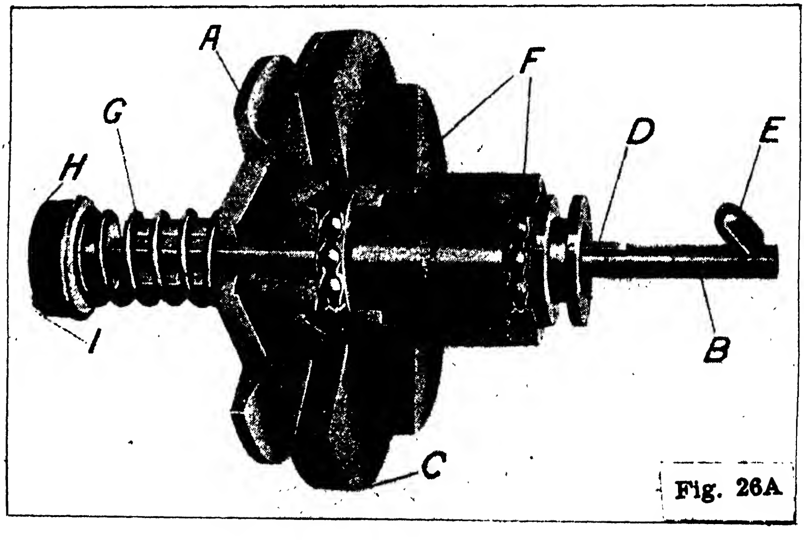


Fig. 26A

WORKING PRINCIPLE OF PROJECTORS

The essential parts making up the mechanism of a projector are shown in the diagram Fig. 26, these parts are not shown in their exact positions, and the relative size of each of the units has been ignored, they are not drawn to scale. The diagram was made for the purpose of showing the relationship of different units and just how the film is driven through the projector from the upper (feed) magazine to the lower (take-up) magazine. The diagram does not show the sound mechanism, we will deal with this later. By turning the crank A, counter clockwise, the main shaft B, is driven through a 4 to 1 reduction chain drive D, a steady turning motion being caused by the flywheel C, this in turn operates the upper (constant running) feed sprocket E, through the 4 to 1 reduction gear F, thus the teeth of sprocket E, which mesh with the film perforations, feed the film at a constant rate, the film being held against E, by pressure roller G.

A film loop or length of loose film is shown between the feed sprocket E, and the top of the gate. The sprocket shown in the diagram at H, and marked "steady drum" is no longer employed in projectors. The film is fed past the film gate intermittently by the action of the intermittent sprocket I, this sprocket being operated by the Geneva movement K, which produces a quick one-quarter turn of I, followed by a long rest during which the main shaft B, makes a revolution.

The barrel rotating shutter L, by a 2 to 1 gear with the main shaft and proper timing, operates to cut off the light rays from the screen during each movement of the intermittent sprocket I, and to admit the light during the intervals that I, remains stationary. The syn-

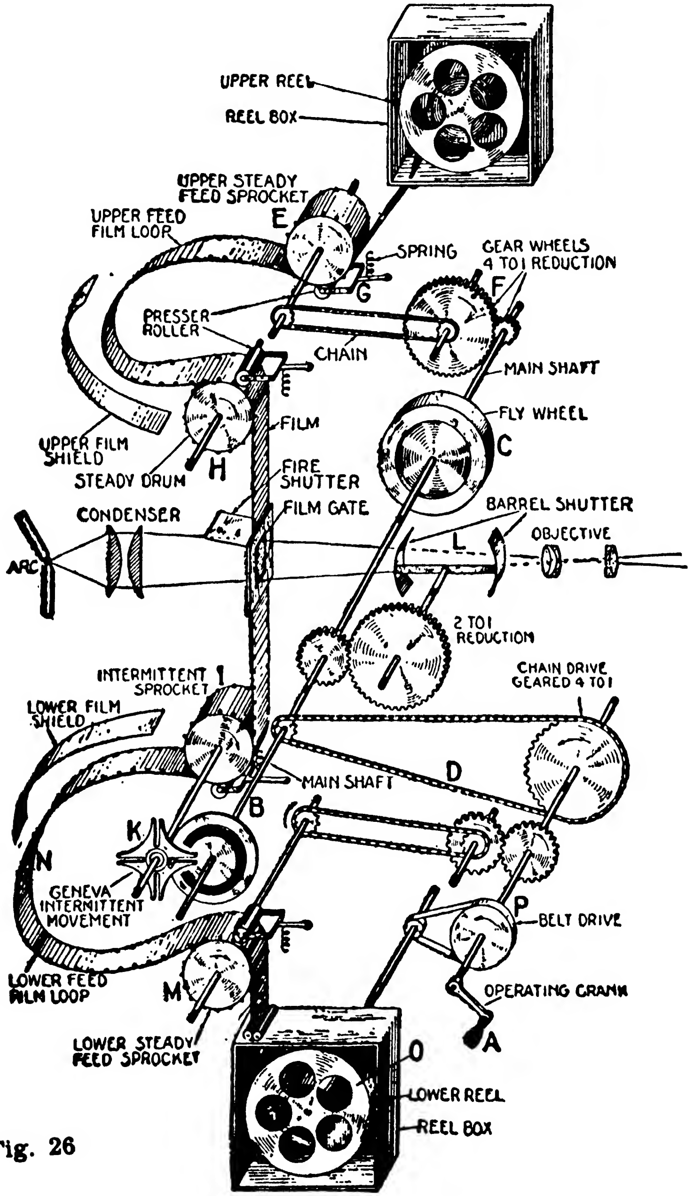
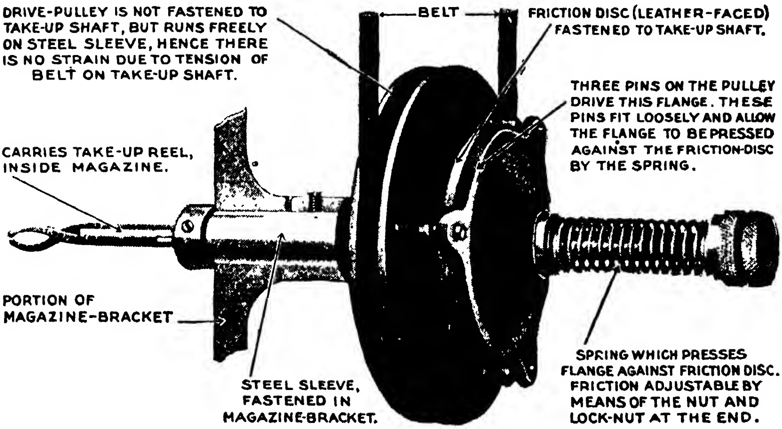

UPPER REEL
REEL BOX
UPPER STEADY FEED SPROCKET
E
UPPER FEED FILM LOOP
SPRING
GEAR WHEELS 4 TO 1 REDUCTION
F
G
PRESSER ROLLER
CHAIN
MAIN SHAFT
FLY WHEEL
C
UPPER FILM SHIELD
STEADY DRUM
H
FILM
FIRE SHUTTER
FILM GATE
BARREL SHUTTER
CONDENSER
OBJECTIVE
ARC
L
2 TO 1 REDUCTION
CHAIN DRIVE GEARED 4 TO 1
INTERMITTENT SPROCKET
I
LOWER FILM SHIELD
D
MAIN SHAFT
B
K
N
GENEVA INTERMITTENT MOVEMENT
P
BELT DRIVE
LOWER FEED FILM LOOP
M
OPERATING CRANK
A
LOWER STEADY FEED SPROCKET
O
LOWER REEL
REEL BOX

Fig. 26

chronous operation of the intermittent movement, sprocket and light shutter as explained in the previous chapter is very clearly shown in this diagram. A lower (constant running) sprocket M, which operates at the



same speed as the upper sprocket E, maintains another film loop N, between the intermittent sprocket and sprocket M, and feeds the film to the lower (take-up) reel O. In sound picture projection the film is fed to the "sound-head" through which it passes before it reaches the take-up magazine, see Fig. 29F.

Because of the ever increasing diameter of the roll of film, due to winding the film on reel O, the velocity of rotation of O, must be allowed to vary, and this is explained later in the chapter.

It should be carefully noted that the total revolutions made by each of the three sprockets E, I, and M, is the same, the only difference being that the motion of sprockets E and M is constant while that of sprocket I is intermittent.

In previous chapters we have covered in detail the workings of the intermittent movement and the rotary light shutter, it may be well however, while this diagram is before us, to treat briefly with some of the other parts making up the mechanism.

FILM MAGAZINES

The magazines are essentially a fire prevention device, motion picture film is highly inflammable, and during its course of travel from the feed magazine, through the mechanism to the take-up magazine, every precaution must be taken to see that it is not brought into contact with heat from the arc-lamp or other light source, the light from the arc-lamp should reach the film only at one point in its travel, and that is at the aperture in the gate, as we progress we will see that the manufacturers of present day projectors have in-

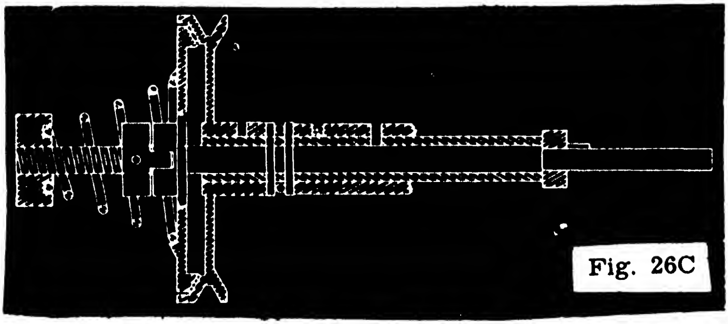
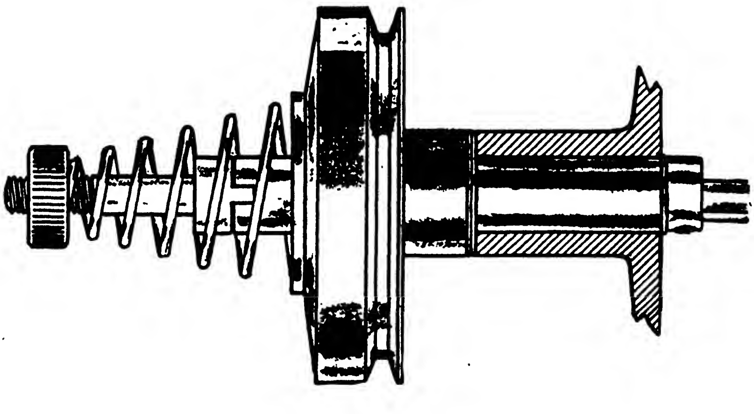


Fig. 26C

corporated every possible fire prevention device.

As will be seen from the diagram Fig. 26, there are two magazines, the upper and lower, the film is placed in the upper magazine, threaded through the projector



head and then on to the lower take-up reel which is placed in the lower magazine. Both magazines are fitted with a fire trap or valve through which the film is threaded, this is a combination of metal rollers and a metal valve, the purpose of which, is to prevent any flame in event of a film fire, entering the magazines. The valve also assists the easy running of the film in

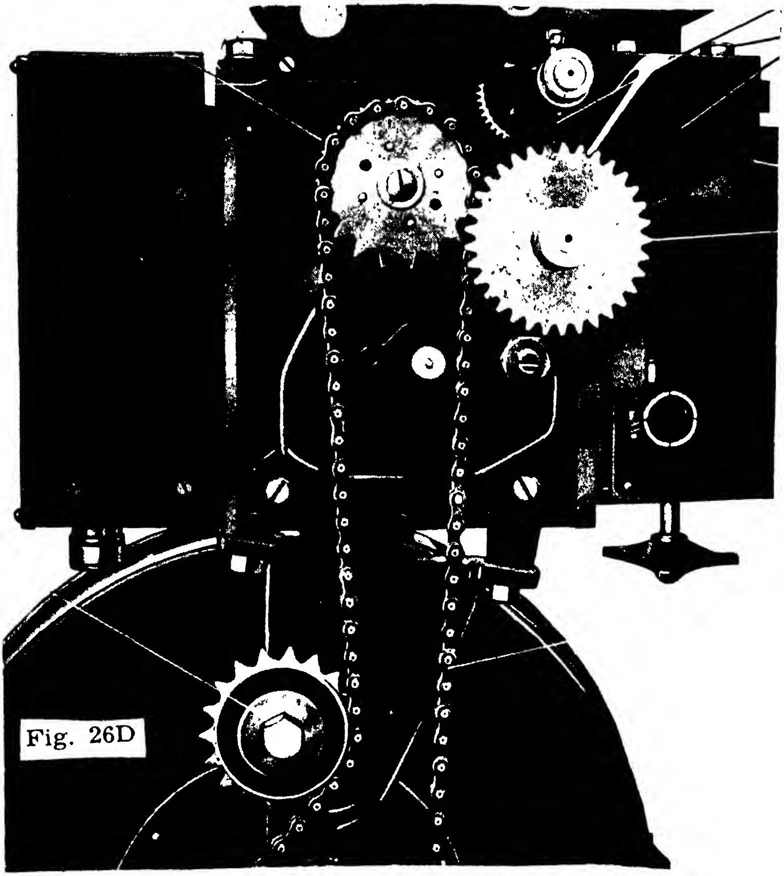


Fig. 26D

and out of the magazines. The location of the valve and its construction can be seen in Fig. 29F, the valve being located just above the words "lower magazine". The motion picture film is drawn off the feed reel in the upper magazine by tension, created by the constantly re-

volving sprocket E. After passing through the mechanism it is wound on to the take-up reel, in the lower magazine, the speed of rotation of this take-up reel varies, it starts off at a maximum speed, and then gradually decreases its speed of rotation as the film is wound on the reel. The variation in speed being controlled by a specially designed take-up mechanism, which will be described in another paragraph.

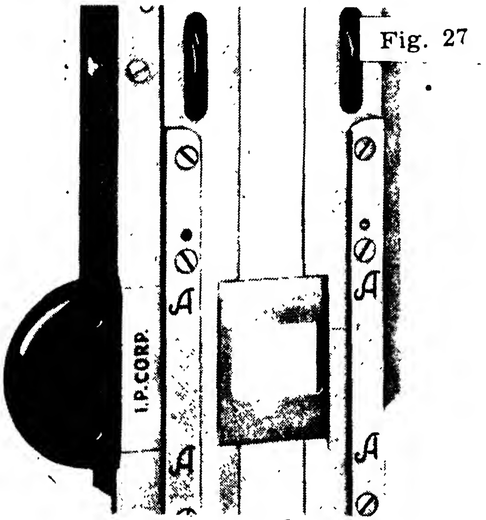


Fig. 27

The magazines require little care, the rollers and valves should be regularly inspected to see that they are clean and that the rollers rotate easily. Care should be taken to see that both magazines are properly aligned, so that the film has a straight path in its travel off the magazine to the upper sprocket, through the mechanism, and from the lower sprocket (or soundhead) to the take-up reel in the lower magazine. Reels should be in such physical condition that they allow the film to be drawn off or wound on without catching the sides of the reel at each revolution, the metal sides should not be bent or damaged and they should revolve easily and freely on the magazine spindle. Where film is received on reels in poor condition, the film should be re-wound on other reels prior to showing.

FILM TAKE-UP

This is the device used to drive the reel in the lower magazine. Film is wound on to the take-up reel at the rate of 90 feet per minute, at the beginning the take-up reel must rotate at a much higher speed than it does

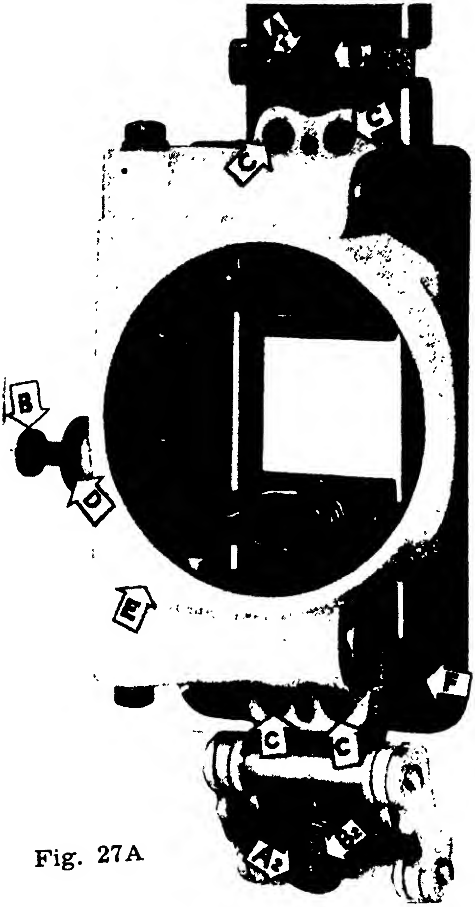
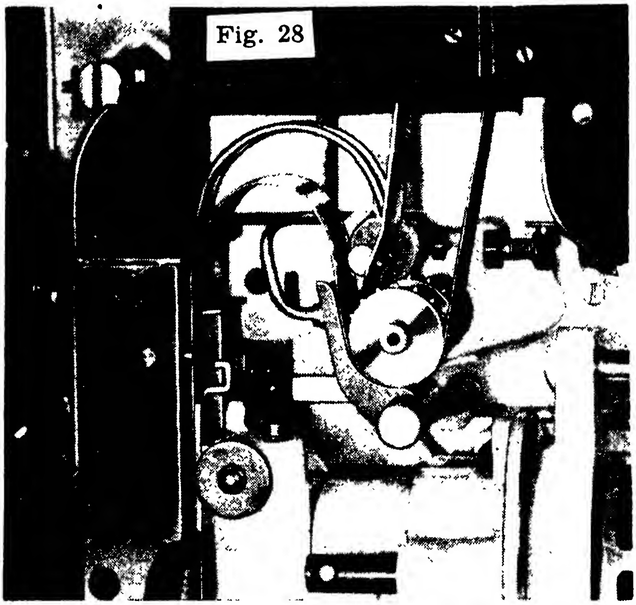


Fig. 27A

as the reel gradually becomes more and more loaded with film, as a matter of fact there is a continuous change in rate of speed from the time the reel first starts until the completed length of film 1,000 or 2,000 feet, has been wound on to the take-up reel.

The take-up therefore has to allow for "slippage" as the roll of film grows in size. In the old Powers projector the take-up consisted primarily of two friction discs, which were held in contact by means of an adjustable spring. One of the discs was faced with fibre to assure a good frictional contact. The driving disc is left free to revolve around the take-up spindle as an axis. The driven disc, is fastened to this same spindle. By frictional contact, motion is transmitted from one disc to the other disc which in turn causes the free



running spindle to rotate. As the weight of the film on the reel increases, this gradually retards the speed at which the driven disc revolves, and this automatically regulates the revolutions of the take-up reel. Fig. 26A, shows the construction of the Powers take-up, a part of the take-up having been cut away in the drawing to show the working principle, the tension of the discs was regulated by the adjustment of the spring. The take-up of one of the older Simplex Projectors is shown in Fig. 26B, this is self explanatory. Fig. 26C shows the

Motiograph take-up and Fig. 26D is the chain drive take-up of the English built Kalee Projector. Modern projectors made in this country can be equipped with either a belt or chain drive at choice of operator

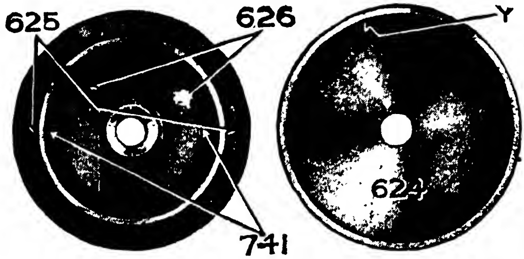
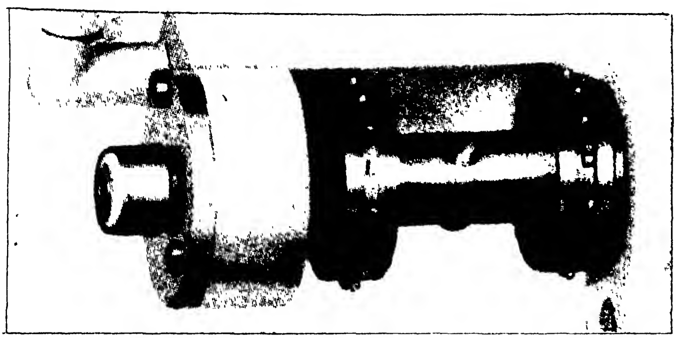


Fig. 28A

SPROCKETS AND IDLERS

As we have already seen the sprockets are film driving members, the teeth of which engage with the perforations on the margin of the film. Sprockets are shown at E, I and M in the diagram Fig. 26. In addition to



these sprockets there are additional sprockets used in the "soundhead", these may be seen by referring to Fig. 29F.

Sprockets should be aligned correctly so that the film has a perfectly straight path in its travel through

the mechanism. The teeth should be kept free of all dirt, film emulsion tends to pile up on the sprocket and this must be cleaned off regularly. As the teeth become worn or bent out of shape, the sprocket should be replaced with a new one. Do not under any circumstances attempt to reverse a sprocket on its shaft as teeth become worn, this is a poor practice which might

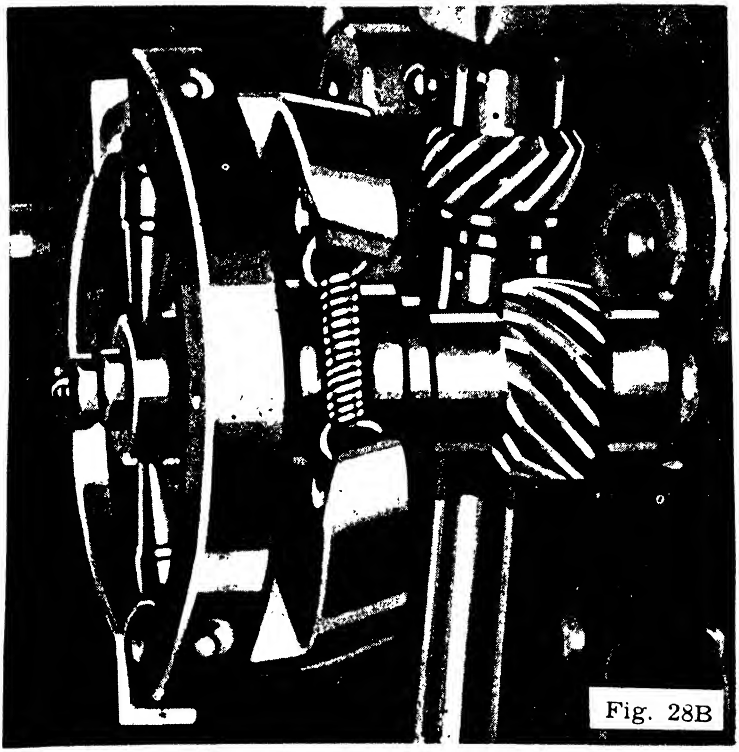


Fig. 28B

result in damage to film, and a bill from the film exchange for many many times the cost of a new sprocket. Instructions for the installation, adjustment and removal of sprockets will be found elsewhere in this book.

Film idlers are used to hold the film on the sprocket teeth and to give the necessary tension to guide the film correctly through the film travel path. These idlers are generally rollers, either one or a combination of two

or more may be used. These should be checked for alignment, and frequently inspected to see that they rotate freely and are not clogged with dirt or film emulsion. The location of the idlers with respect to the sprockets can be seen in Fig. 29F.

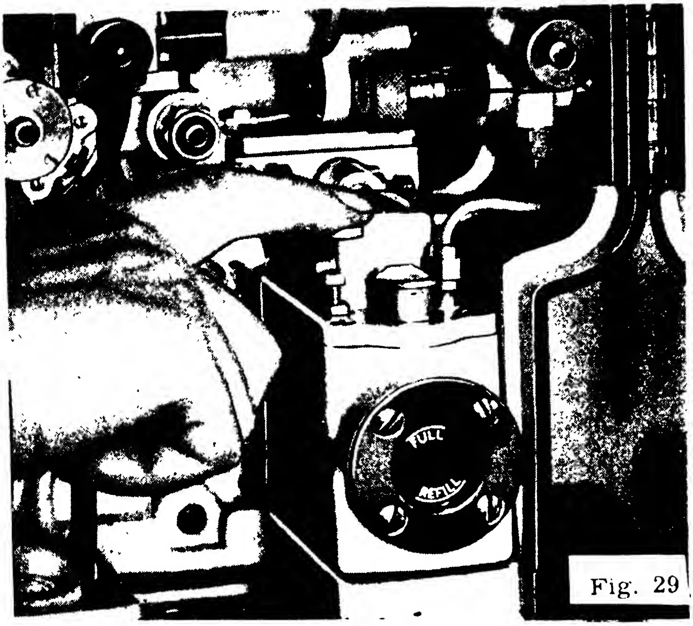
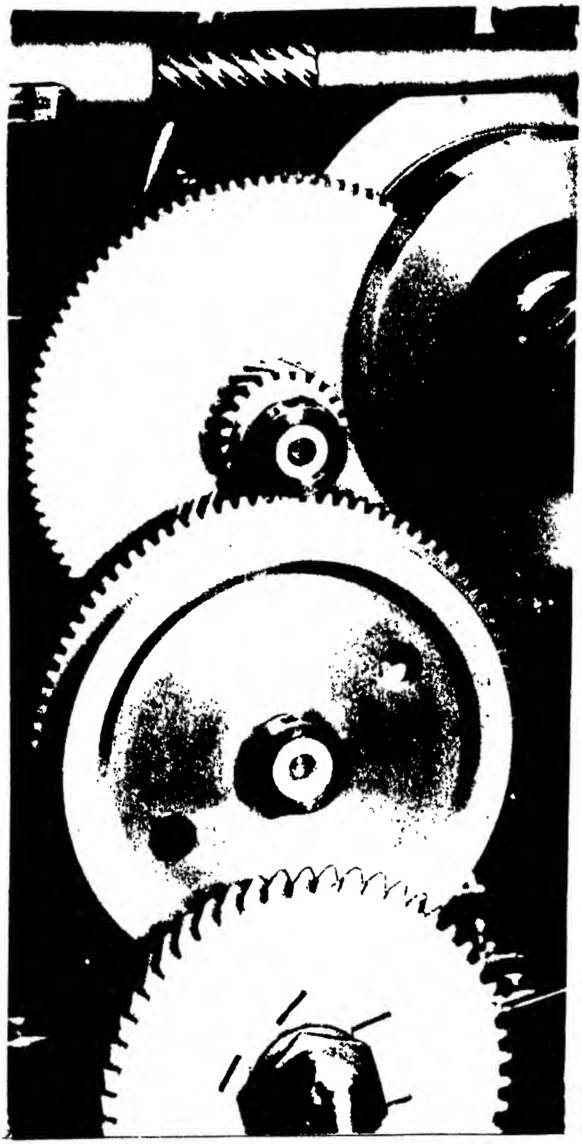


Fig. 29

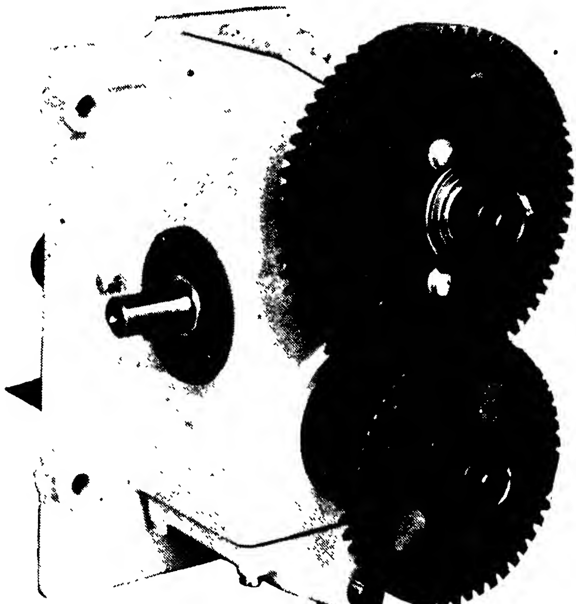
FILM GATE

The film gate is positioned between the upper feed sprocket and the intermittent sprocket, in the gate is the aperture, which acts as the frame for each of the individual film pictures as they are projected on to the motion picture screen. It is in the gate that the film comes to rest, during that period of time the intermittent movement is at rest. The aperture is in alignment with the source of light and the objective lens, if a straight line could be drawn from the arc, through the dead center of the condensers, through the center of the gate aperture and on through the objective lens this would represent the center of the "optical train" of the projector.

The gate is supplied with a series of "runners" or "tension shoes" so adjusted and located that the film will have no by-play or back-lash as it passes through the gate. Insufficient tension may result in an in-and-out



of focus" effect on the screen, while too much tension will show up as an unsteady or jumpy picture on the screen and may cause film breakage, especially at points of broken perforations or at poor film patches. The tension shoes or runners should be frequently checked to see that they are free from film emulsion, which has a tendency to build-up on the shoes, especially when using "green" film. In removing emulsion from



the runners care should be taken to see that they are not scratched in the process, as this will only aggravate the trouble, use a soft metal to remove the emulsion, the edge of a one cent piece will answer the purpose. The runners must be kept smooth and clean at all times if trouble is to be avoided. The gate aperture should be cleaned out frequently, otherwise the projected picture will have "whiskers" around its border. Fig. 27 and Fig. 27A show the front and rear of the Simplex gate.

AUTOMATIC FIRE SHUTTER

The aperture in the gate of the projector is pro-

tected by an automatic fire shutter so controlled and adjusted, that in case of a film fire or a stoppage of the film, other than for that period of time necessary for the projection of the picture, this shutter will automatically cut off the light from the film.

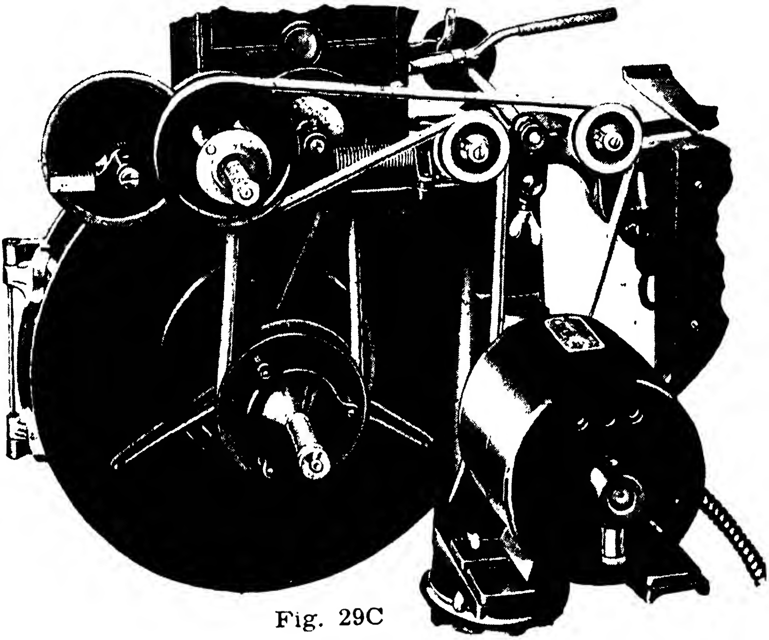


Fig. 29C

As the name implies it is another of the fire prevention devices provided by projector manufacturers. Generally the shutter, which covers the aperture and thus cuts off the light rays, will not open until the projector (and the film) has gained a sufficiently high rate of speed, and should the projector speed fall below the safe working speed the shutter again drops, and cuts the light off the film.

In some projectors, like the Simplex E-7, the automatic shutter will drop, even if the projector has attained full operating speed, should the film for any reason remain stationary in the gate for a longer period than necessary. In the Simplex the device is known

as the Automatic Fire Shutter Trap, and it can be seen in Fig. 28, it looks like an ordinary hairpin shaped into a half circle, and is located between the upper sprocket and the top of the gate. Should the loop of film, "build-up" for any reason, it will make contact with this wire loop, and this will immediately drop the fire shutter. The shutter cannot again be lifted until the projector is stopped and the piled-up film removed.

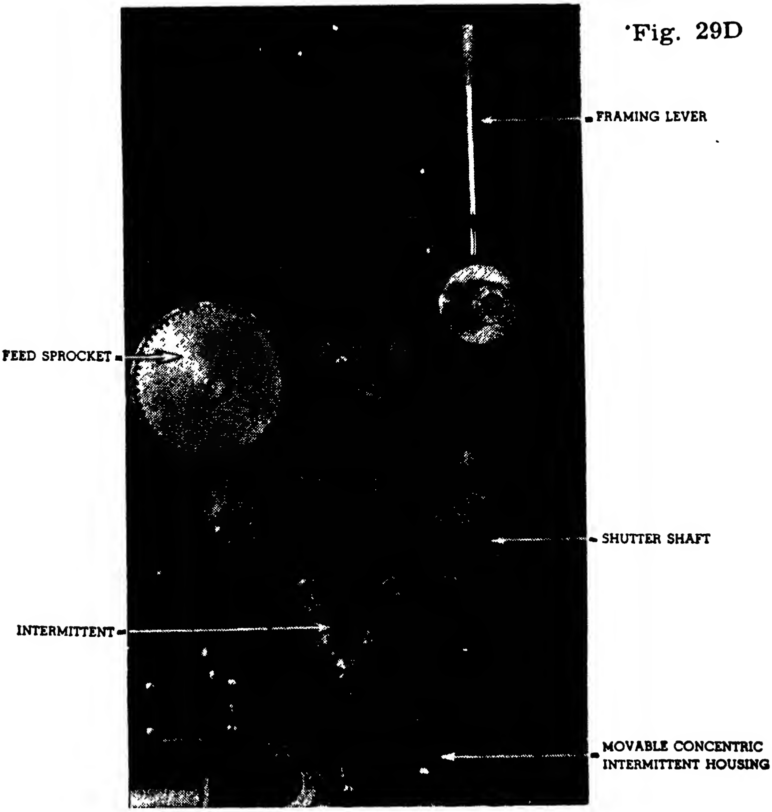


Fig. 29D

All projectors are equipped with some form of fire shutter, the construction and operation of the shutters being different in different makes of projectors, all however depend upon the principle of centrifugal

force for their action.

Fig. 28A shows the centrifugal movement which operated the fire shutter of the old Powers Projector, with the outside cover removed. The outside cover is numbered 624 to the right in the illustration, Y points to the inside of the rim of the cover. The inside of the movement is shown at the left, the arrows 625 point to two engaging studs, which, because of centrifugal force, are thrown outward as the projector gains

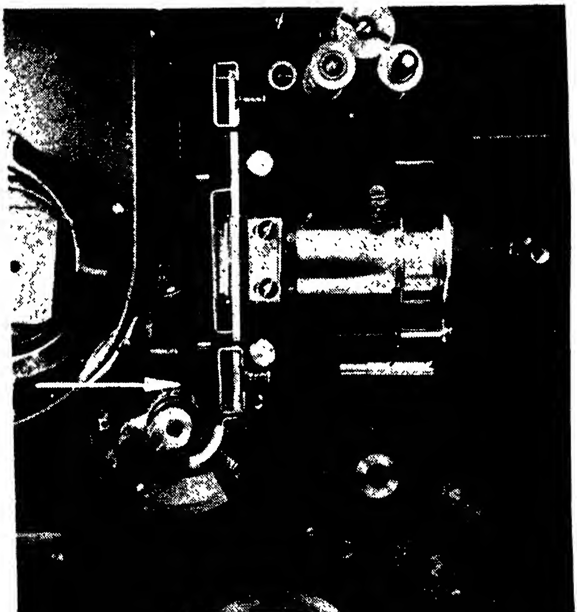


Fig. 29E

speed, eventually engaging with the inside surface of the rim Y, on the cover. It is important that the surface of the rim be kept clean and smooth as the two studs only make a sliding contact. As the studs engage the inside of this rim, this naturally revolves the cover 624, in a clockwise direction, and this in turn forces a lever (not shown in illustration) which in turn raises the shutter to which it is attached.

Fig. 28B, shows the governor movement of the

Motiograph projector. This governor is driven directly from the diagonal shaft through gears which assures positive action, there is a direct action coupling which eliminates all connecting links.

We have now covered all the important parts making up the mechanism, with the exception of the driving gears, the framing device, the mechanism driving unit and the objective lens.

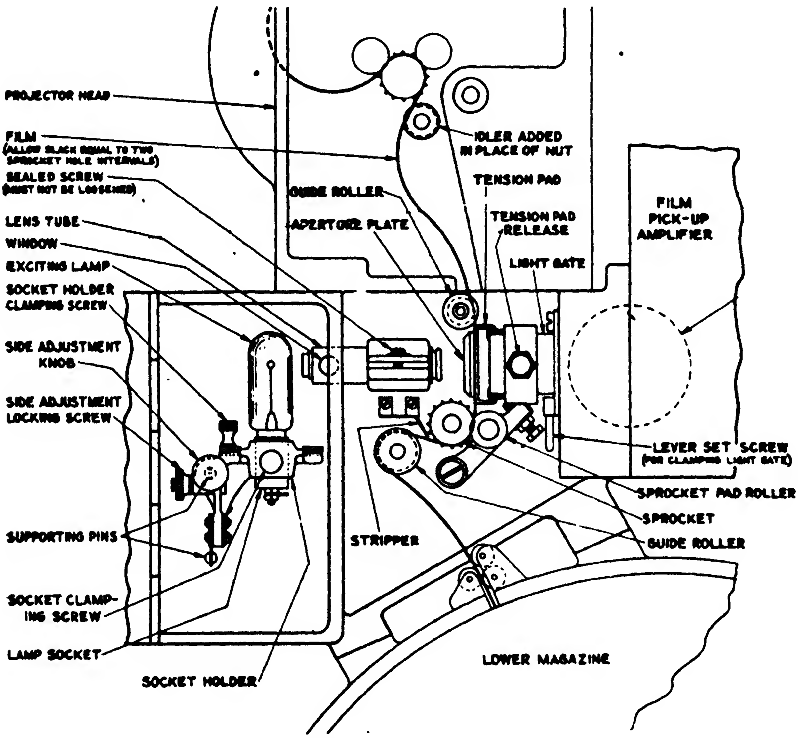


Fig. 29F

Lenses and light are all important to projection, and an understanding of the theory of light is daily becoming more and more important to projectionists, so we will for the time being skip the subject of lenses and devote a special chapter or more to this later in the book.

There is little to say regarding gears, the reader will undoubtedly be more or less familiar with these. Those used in motion picture work are all case hardened or fibre gears, generally a combination of the two will be found in all modern projectors. These are precision fitted before leaving the factory and should require little attention other than lubrication. Lubrication of these gears, in fact lubrication of all parts of a projector should be done by following the instructions given by the manufacturer. After a period of time inspection should be made of gears to see that there is no back-lash or lost motion due to wear. The gears of the RCA Rotary Stabilizer are shown in Fig. 29B, Fig. 29A, shows the gear train in the Simplex E-7.

It is well to remember that wherever there is friction there should be lubrication, if trouble is to be avoided. Elsewhere in this book will be found lubrication charts covering lubrication of projectors, sound and associated equipment, these should be followed for best results. Fig. 29 shows the new Simplex E-7 oil plunger and oil reservoir. Lubrication of all working parts in this new projector is accomplished simply by pressing on the oil plunger at certain intervals, the oil drips back into the reservoir, where it is filtered prior to being shot through the mechanism again.

The projector mechanism is driven by means of a motor, which requires the care and attention necessary to all other type motors. Complete data on motors will, however, be found elsewhere in this book. The motor drive and speed control of the Simplex Projector is shown in Fig. 29C.

FILM FRAMING DEVICE

As the name implies this is the adjustment, manually operated by the projectionist to "frame" the individual film picture in the gate aperture. The film should of course be correctly framed in the aperture when threading the projector, then providing the film is free from a "mis-frame" patch, there will be no necessity for using the framing device during the running

of that specific reel of pictures. However, even though the film is correctly framed prior to projection, it may run out of frame during the projection of the reel, and it is for the purpose of returning the film into frame that the framing device is provided, this being done while the projector is in operation. We have always taken the position that the inspection of motion picture film should be done at the film exchange and not at the theater by the projectionist, however, as a precaution it is well to run the film over on the rewinder prior to projection. A novel method of framing is employed in the DeVry 35 mm. projector as shown in Figs. 29D and 29E.

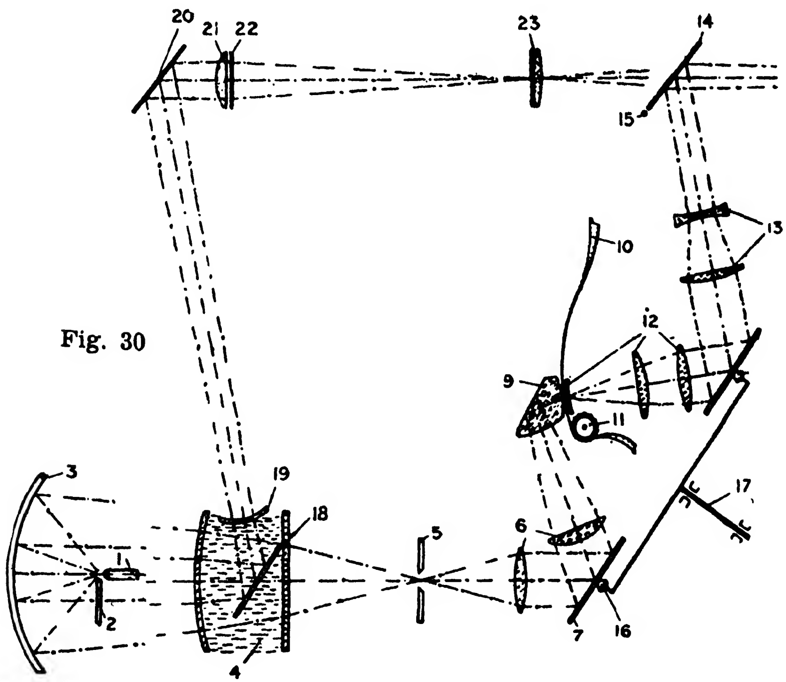


Fig. 30

SPECIAL PURPOSE PROJECTORS

In this chapter it is our intention to deal with projectors of other than conventional design or construction and projectors though of conventional design used for special purposes.

CONTINUOUS PROJECTORS

By continuous projectors we mean projectors in which the travel of the film past the gate aperture is continuous and not intermittent, we are not considering the projector used for advertising purposes in store windows in which the film is automatically re-wound after passing through the projector, so that a continuous, uninterrupted performance may be given.

The continuous projector may or may not be equipped with a rotating light shutter, but we will deal with continuous projectors which not only have a continuous film movement past the aperture, but also continuous non-periodic screen illumination.

THE MECHAU CONTINUOUS PROJECTOR

This is a German product, built by Dr. Mechau and named after him, though the projector was marketed under the name of the Arcadia Projector in England. As far as the writer knows, only one of these projectors reached this country, and this was installed in the Capitol Theater on Broadway, New York City, and used only in projecting the newsreels, and special short subjects.

As will be seen by referring to the diagram Fig. 30 and the photograph Fig. 31 the projector offers a radical change in projector construction. First let us take up the matter of lighting. The arc-lamp is of the

mirror type (3) with a right-angle carbon feed which is automatically controlled by a device requiring no extra circuit or power consumption. The light which is reflected from the mirror passes through the water condenser (4). This has of course the effect of cooling the light rays. From there it passes through an aperture and light cut-off (5), and so on to the small lens (6), thence to the lowest section of the rotary mirrors (7). From the mirror the light is reflected through another lens (6) and so on to the prism (9), thence through the projection lenses (12) and then on to the topmost section of the rotary mirrors (8) from which

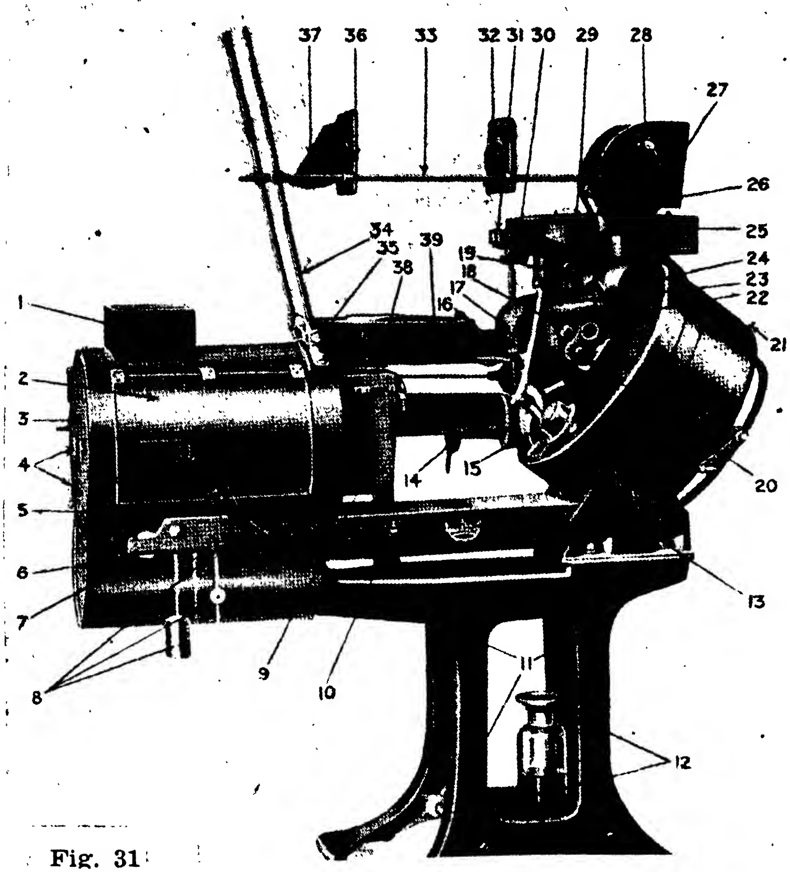
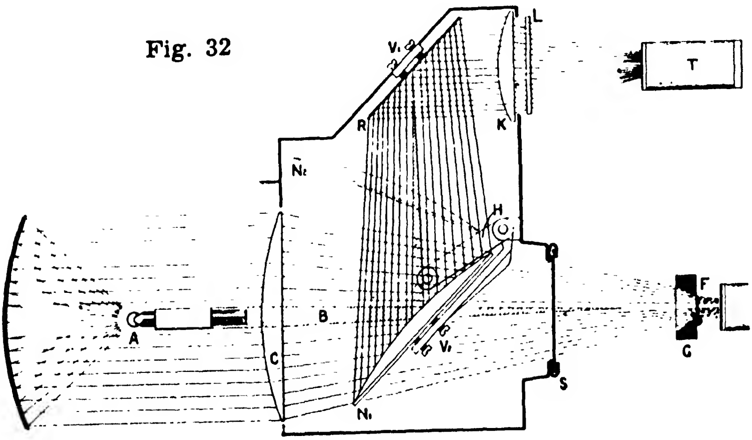


Fig. 31

the picture is reflected through tele-objective lens (13) on to the projection mirror (14) and so to the motion picture screen.

In the diagram, (10) is the film passing through the continuous feed, while (11) is a portion of that feed. It will thus be seen that the light is never directly on the film.

Fig. 32



For slide projection, a novel method is used. In the diagram (18) is a dividing mirror for use in slide projection, this mirror can be kept in position during actual projection of the film. When this device is in position the light is diverted on entering the water condenser, and is reflected by the mirror (18), through the condenser (19) on the top of the stationary mirror (20), thence through the condenser (21), slide carrier (22), lens (23), on to the screen, when the projection mirror (14) has been lowered by a simple movement. Thus the slide can be projected through the same aperture as the film, and can be shown immediately the film is ended, and even before the end of the trailer has passed the gate aperture. Or slides can be projected at any movement intermittently in conjunction with the running of the film.

A similar slide projection method is used in the

English Kalee Projector, shown in Fig. 32.

Now we come to the method employed to obtain the continuous, non-intermittent action. On intermittent projectors, sound pictures are projected at the rate of 24 frames per second, each picture remaining

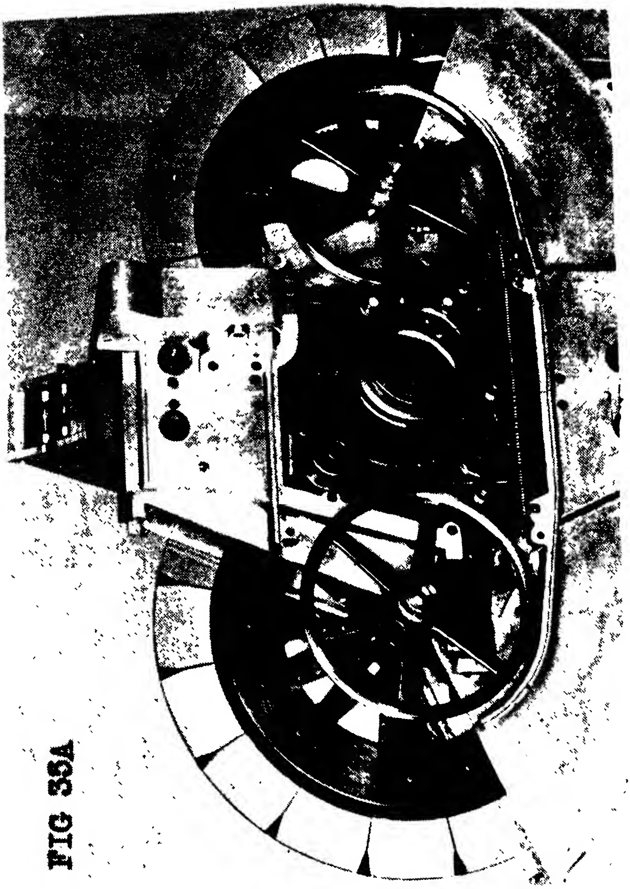


FIG 35A

on the screen and stationary in the gate aperture for a certain definite period of time, after which the shutter comes into operation, the light is cut off from the screen, the film given a quick jerk by the intermittent movement and the next succeeding picture is in position to be shown. This combined action continues

through the whole length of film.

In the Mechau Projector, the film is placed in the top magazine and threaded, using the usual sprockets and idlers, and then connected to the take-up reel. The gate, which has an aperture large enough to hold two frames of pictures, is bow shaped, having no tension

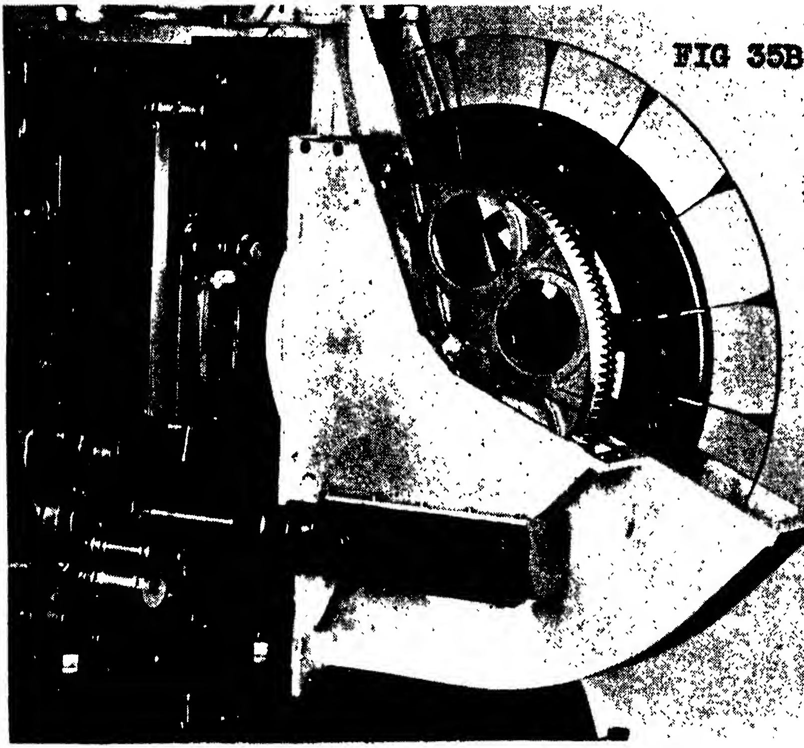


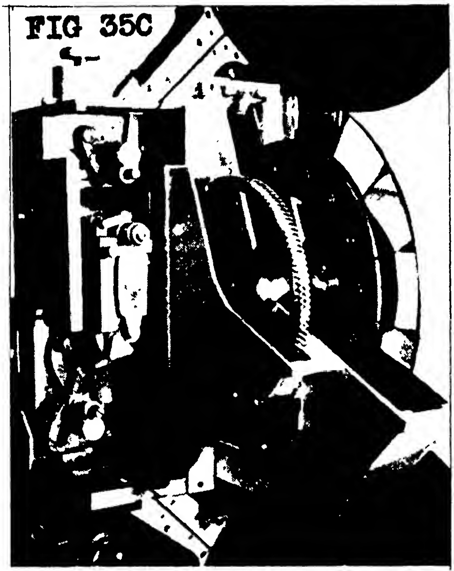
FIG 35B

springs, and because of its shape, requiring no tension whatsoever to retain the film in position in its passage through the gate. In the diagram the gate is shown dropped to its full extent, this is to show the feed, in practice the gate is only dropped to its full extent for cleaning purposes.

Behind the film, as shown in the diagram, there is the projection lens, which in its turn superimposes two frames of picture onto the screen. There always

being two pictures on the screen, the action of the light, in connection with the action of the rotary mirrors, is that as soon as the first superimposed picture begins to lose its light the next picture picks up the exact amount of light lost by the first picture. In this way no part of the light is ever shut off the screen at any time. The compensating action of the rotary mirrors, in conjunction with the light and continuous feed, dispenses with the necessity of a rotating light shutter and the intermittent action used in standard projectors.

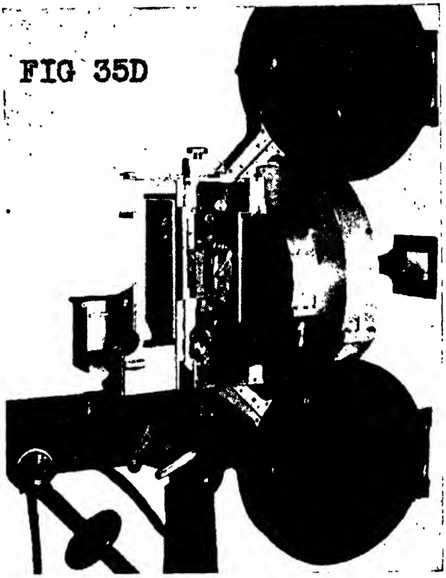
FIG 35C



The manufacturers of the Mechau Projector make three claims for it, over the usual type of intermittent projector, first, that the continuous projector is the ideal projector for projecting sound pictures, second, that the continuous projector is much lighter on film wear and tear, because it eliminates the constant stopping and re-starting necessary with intermittent projectors, and, thirdly, that by eliminating the rotating light shutter, there is a 50% saving in light.

We cannot, however, agree with these claims, as selling points, nor with the third claim as a matter of fact. With the advent of sound pictures several years

FIG 35D



ago, the Fox Film Corp. made a series of tests over a period of time with the continuous projector, the writer was on the committee making these tests, and a decision was brought in favor of the intermittent projector. Points against the continuous projector were that its original cost was high, that repairs to the rotating mirrors would call for expert experienced labor and that the operation of the projector would call for a new operating technique for projectionists.

We are willing to grant that by using the non-intermittent projector that the physical life of film would be materially lengthened. But this selling point has little if any effect on exibitors, who do have to purchase the projector, but only hire for a peoiod of days or hours the film they use.

The 50% light saving claim due to elimination of the rotary light shutter, is more than offset, if one will

just figure the various light losses (light reflection loss is about 4% at each glass to air surface) through the optical train of the continuous projector, and in addition to the reflection and absorption losses, we must also take into consideration the fact that two frames of pictures must at all times be illuminated in the gate aperture, as against one frame in the intermittent projector, this calling for a much larger light spot and thus greatly reducing the effective light at this point.

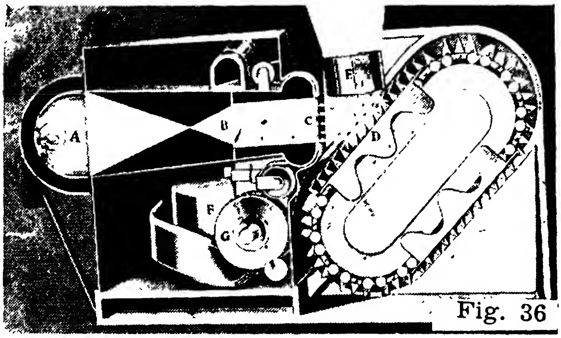


Fig. 36

GUMMAX NILSEN VIG CONTINUOUS PROJECTOR

This projector has an optical compensation very much like the Mechau projector. In Vig's projector one oscillating mirror is placed between the objective lens and the screen, whereby the curved gate needed in the Mechau projector and the necessary correction for the curve through a torus lens is obviated. Another oscillating mirror is placed between the film gate and the condenser. Thus the number of mirrors has been reduced from eight to two, with a corresponding saving in light. The mechanism, which causes the oscillation of the mirrors and also makes the pictures intermittent, is entirely different from that used in the Mechau projector, outside of these changes the operation and construction is similar.

HOLMAN CONTINUOUS PROJECTOR

The continuous projector built by Arthur J. Holman of Boston, Mass, is the best known of the American built continuous projectors.

The objective used in the Holman projector consists of a stationary front component having its optical center on the optical axis of the projector and movable rear components which are carried on the peripheries of two overlapping revolving lens wheels.

The lens wheels are alike in construction; the periphery of each consists of a plurality of identical simple positive lenses. The lens wheels rotates in synchronism at a uniform angular velocity and constitute the only moving parts of the optical system. It is to be noted that variable refraction results from the movements of the optical centers of the rear components of the objective toward and away from the optical axis of the projector as the lens wheels rotate.

The lens wheels as constructed for standard theater projectors, consists of a solid flange supported by spokes from a hub which is screwed to a lens wheel shaft. The solid flange has a surface to which the axis of the lens wheel shaft is perpendicular and against which are clamped, by individual flange sections, the identical plano-convex lenses forming the periphery of the lens wheel. These lenses must be positioned very accurately; their plane sides must lie in one plane and their optical centers must lie on a common circle about the axis of the lens wheel shaft and must be equally spaced. The lenses are correctly "set" on the lens wheels by means of a precision optical instrument which insures correct positioning with a medium expenditure of time. The lens Wheels are each made up as a unit and are ready for service as soon as they are placed in a mechanism. Fig. 35A shows a front view of mechanism with cover plates removed, showing lens wheels, balanced drag mechanism and mount for front element of objective. The rear-right side of the mechanism with door and cover plate removed is shown in Fig. 35B.

Other optical features of the projector include a curved aperture plate having an opening approximately two and three-quarter frames high, a gate lens positioned just behind the film at the aperture plate, and a sphero-cylindrical element in the condenser system. When using a reflector arc of the type employing no condenser a special reflector is required in place of the parabolic mirror. The special condenser element or the special reflector, the gate lens, and the elongated aperture are required to increase the efficiency of light transmission and to produce the proper convergence of the light rays into the objective system. Fig. 35C is a close-up of projector head, showing the gate mechanism while Fig. 35D is a general view of projector, without lamphouse.

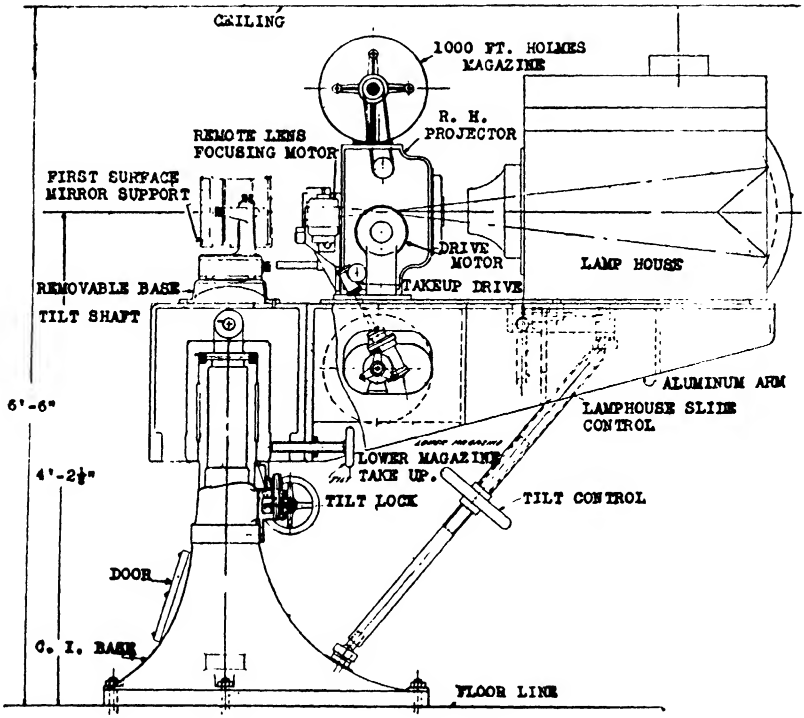
The transition from frame to frame on the film strip takes place by means of an automatic dissolving action resulting from the passage through the beam of light of the lenses on the revolving lens wheels. The lenses are so proportioned that the dissolving action occupies a major portion of the picture cycle and consequently the images of the two frames are superimposed on the screen during the greater part of the time of projection.

COMES CONTINUOUS PROJECTOR

This continuous projector uses a series of rotating objective lenses in place of rotating mirrors. Eight objective lenses, all of the same characteristics are mounted on levers and controlled by cams, these move in synchronism with the continuous moving film so that each objective lens projects a stationary picture, the image of a single frame, during its entire passage before the gate aperture. The dissolve between frames taking place as one lens moves away and the following lens takes its place before the aperture.

It is claimed that a rate of projection as low as eight frames a second gives illusion of continuity. Another continuous projector of foreign make, was of comparatively simple construction, this utilizes a spiral concave mirror with an inner hollow face, which

rotates on a vertical axes once for each picture frame. Fig. 36 shows a portable 35 mm. projector used for continuous film showing, the projector has an intermittent and the film is re-wound automatically after



passing through the projector. It was used for shop window advertising.

BACKGROUND PROJECTORS

The background projector was developed to project moving pictures used as a background in studios while pictures are being photographed. Thus actors sitting in a gondola in a tank in a Hollywood studio, with motion pictures of the canals of Venice being projected by this projector onto a screen in the background of the action, appear in the finished picture, to be sailing

along some Venetian Canal.

The projector is built along traditional lines,, yet there are sufficient novel features incorporated to warrant its inclusion in this chapter. The projector described was built by the International Projector Corp.,

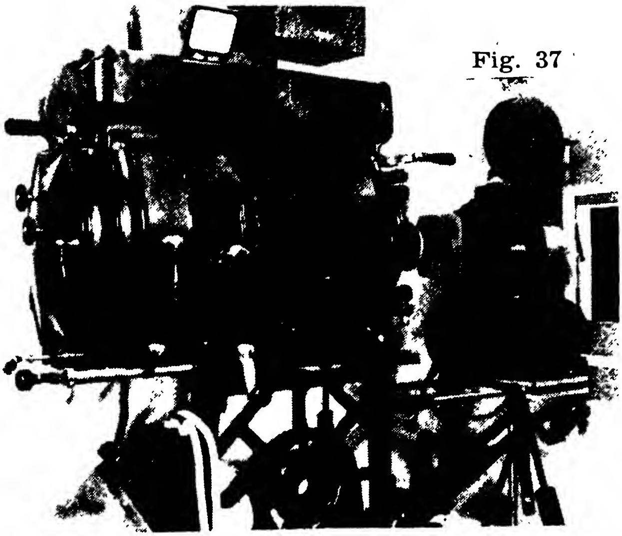


Fig. 37

The complete unit is composed of a specially constructed Super Simplex mechanism, the usual upper and lower magazines, and a super-intensity lamp. Fig. 37 is an illustration of the Simplex Background projector. Figs. 38, 39 show how background projectors are used in the making of motion pictures.

The projector mechanism is built especially for the work it must do, and commercial tolerances acceptable for theater projection are eliminated in the construction of the process projector. The film-trap, for instance, is very accurately constructed, and is equipped with edge-guiding means in order that the picture may be absolutely steady laterally, and provision is made in the film-trap design and construction for judging the projected picture to determine what causes any unsteadiness that might be present.

For example, with this equipment it is possible to project a sprocket hole in the film, and if the perforations in the film are accurate—and they usually are—the image of the sprocket hole upon the screen is absolutely steady, both laterally and vertically. If the negative is projected and the camera frame line moves with relation to the perforation, that is a definite indication that the camera movement is not steady. If the positive

is projected and the positive frame line moves with relation to the sprocket holes, that is a definite indication that the camera or the printer was unsteady; so that it is possible to observe and analyze satisfactorily any defect that may be present in the master print for process projection and thus eliminate endless discussion as to where the fault resides.

The intermittent movement of this particular equipment is of the Geneva type. It is manufactured to practically zero tolerance, and steadiness of the movement is carefully checked with a special test-film.

The lower section of the upper door on the non-operating side of the mechanism has been removed, thus

making it possible to remove the door after removing the hinge screws. Thus it is possible to get into the non-operating side of the mechanism should it become necessary to do so. The lower door section may be removed in the same manner. A grease cup is provided for lubricating the rear shutter shaft, a single turn of which suffices to force sufficient lubrication into the ball bearing. A special lubricant has been developed for this purpose.

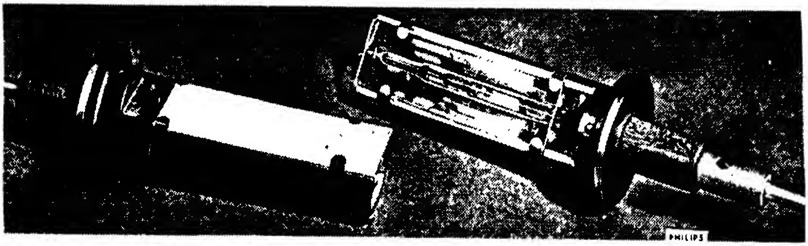
Fig. 39

The intermittent movement of the projector, as is the case with the camera, when properly interlocked operates at 1440 frames per minute—standard photographing and sound recording speed. Adequate provision is made to adjust the projector and camera movements to the interlocking motor system. The coupling flange on the intermittent movement is so designed that it may be secured to the shaft in any position. It is necessary only to open two clamping screws, rotate either the motor or the intermittent movement shaft while the one or the other is standing, and clamp the flange tightly again after the proper position is attained in synchronism with the camera shutter movement.

If a "hot spot" occurs at the center of the screen, it

is possible to remove it by mounting a small circular disk cut from fine copper mesh exactly in the center of the light-beam at the proper point in front of the lens. Experiment will definitely determine the distances required with lenses of different focal lengths.

There is, of course, very noticeable flicker upon the screen when using this type of projector, due to the single-bladed shutter that is used, so that it should not be used for normal projection of motion pictures. It is purely for process work, and, naturally, flicker is not noticeable to the synchronized camera under such circumstances. Should it be required to project standard motion pictures with this equipment, the shutter must be removed and the standard two-bladed shutter substituted.



PROJECTOR WITH MERCURY SOURCE

Early in 1944 the North American Philips Company presented particulars of a new type of light source for a 35-mm projector. The light source used is a water-cooled high pressure mercury lamp. The projector with the new lamp differs in appearance and construction from the projectors in use today.

The light tube is of quartz. Two tungsten wires led in through the ends of the tube serve as electrodes. In addition to a small amount of mercury, the tube contains some Argon gas to facilitate ingition. The mercury vapor pressure is over 100 atmospheres and the light flux is 60,000 lumens. The D. C. voltage is obtained by means of a special rectifier. Ignition voltage is 800 and working voltage is 500, current is 2 amperes.

The quartz tube is mounted in a semi-cylindrical housing as shown in Fig. 36A. Light emitted backward by the lamp is directed forward by a special mirror, this is shown in Fig. 36B. If the rays paths are examined in a transverse cross section, four images can be seen in addition to the discharge. Together

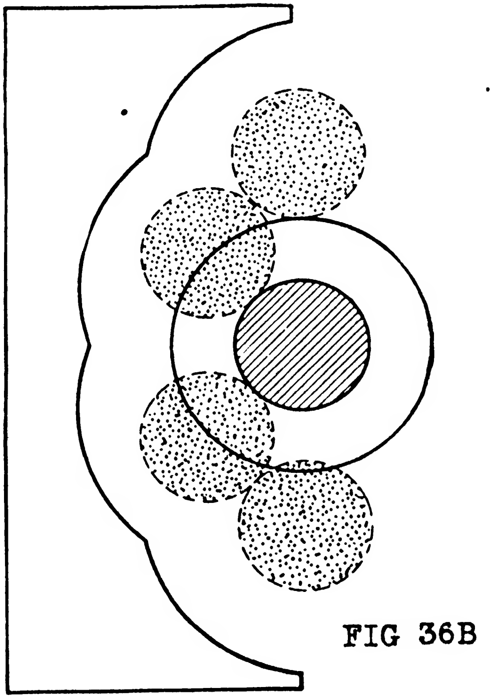


FIG 36B

they form a lighted surface about 0.316 inches in width. In the longitudinal section, there is no focusing, this is unnecessary because of the oblong form of the light source giving sufficient angle of divergence. Figs. 36C and 36D show cross section of the design of optical system. A plano-convex lens receives light from the mercury lamp at a divergence angle of about 90 degrees. Refraction of this lens is relatively small because one surface is bounded by water instead of air, therefore, a second condenser lens must be used. The

shutter rotates in the space between the lenses.

Circulating water is used to cool the lamps and is supplied through a hollow-tapered shaft on which the lampholder is mounted, only the lamp in operation is cooled.

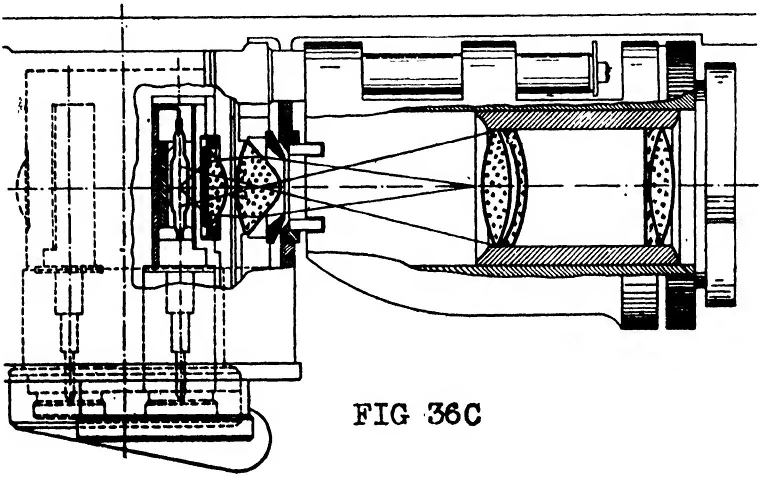


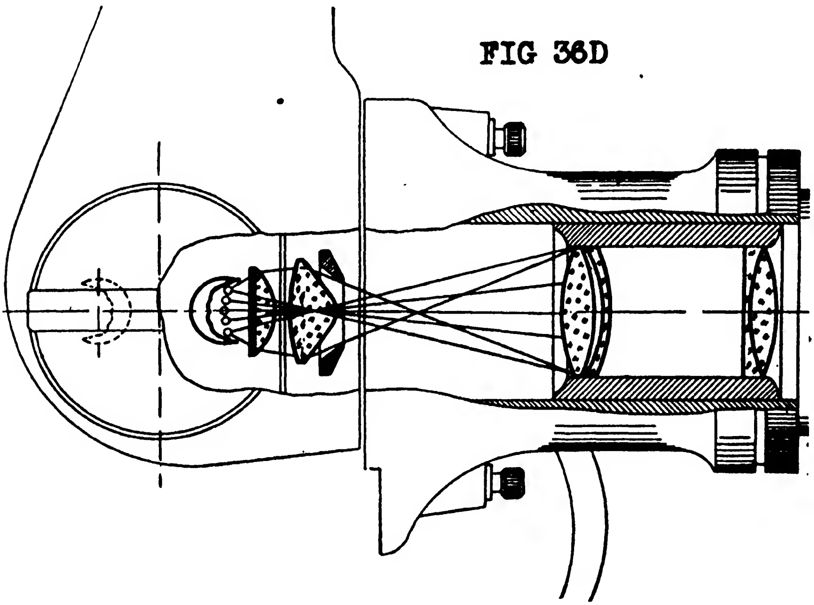
FIG 36C

Twin projector construction is made possible by use of the mercury lamp. Film magazines are mounted in the space ordinarily occupied by the carbon arc, and the monitor speaker is mounted on the base.

Control panel, from left to right, carries two switches for controlling treble and bass notes, and two plug-in switches for regulating volume from projection room or the auditorium. Below the volume-control is a switch that connects monitor speaker to either amplifier. To the right are the volume control and three plug-in switches for film, phonograph, or microphone reproduction. There is also a lever switch for sound and picture change-over. The complete mercury lamp projector is shown in Fig. 36E, while Fig. 36F shows an inside view of the operating side of projector. The two upper compartments are identical in layout, they contain, from left to right, a pre-amplifier, a projector housing, a driving motor, a take-up clutch and a con-

troller drum which provides necessary connections for the projector, motor, mercury lamp and safety switches. In the lowest of the three compartments are the amplifiers and power supply systems mounted on pivot points so they can be turned to facilitate inspection and servicing. The two projector mechanisms are shown in Fig. 36G, each mechanism can be rotated

FIG 36D



to provide an inclination angle of 20 degrees downward and 10 degrees upward. The soundhead is incorporated in the projector and the rotary sound drum shaft is coupled to a dynamically balanced flywheel. The framing device, control lamps, the film break switch and ammeter are also mounted on the operating side of the projector. Shown in Fig. 36H are the gear mechanism, intermittent housing and flywheel of the rotary sound

PROJECTION OF COLOR FILMS

All color-photographic processes fall into two groups; the Additive process or the Subtractive process, some combine the two.

Briefly, in an additive process, the film itself carries no actual color; the color-values are latent, and are revealed by appropriate filters placed or moved between the film and the screen. In a subtractive process, the picture is in itself a complete, self-contained, color-record, needing no filters or other special equipment for projection. Each of these systems has its individual advantages and disadvantages. For in-

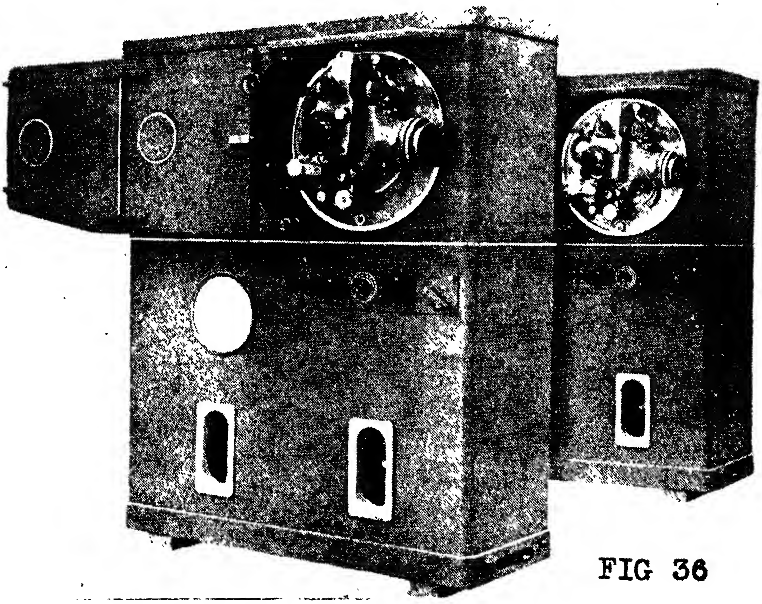


FIG 36

stance, the additive processes' films are in no way special, and may thus be handled in the ordinary manner: but at the same time, special apparatus is required for both taking and showing. On the other hand, though the subtractive processes require special cameras and special processing, their films may be run on any projector—a great commercial advantage.

Now, further than this, the additive processes divide into two categories: those whose seperate color images are made and shown successively, depending upon persistence of vision to form the combined color-pictures; and those whose separate color-images are

taken simultaneously, and superimposed by projection, giving a single, complete color-picture on the screen. Obviously, the first of these two is by far easier to handle, but it has the disadvantage of creating a considerable strain on the viewers' eyes—generally causing severe frontal headaches from the optical effort

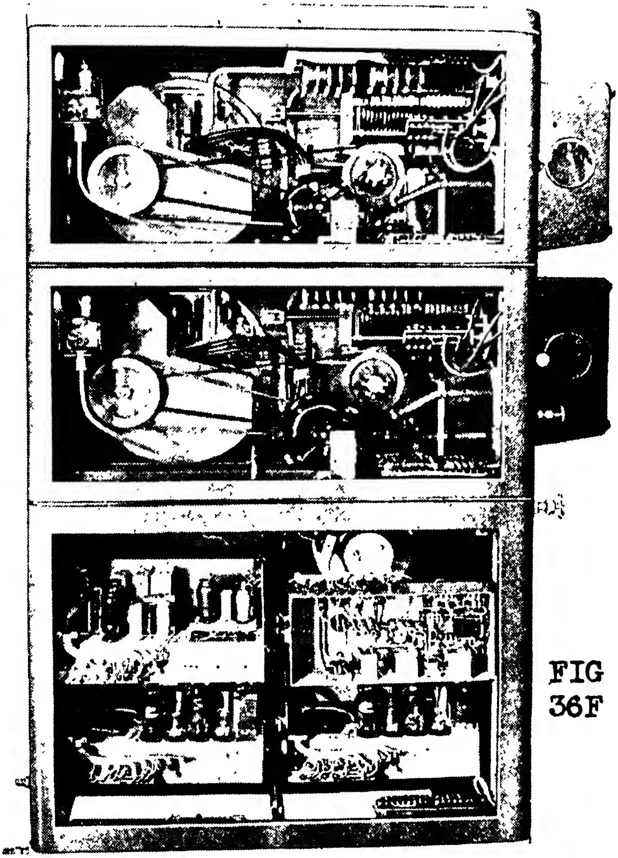


FIG 36F

of combining the several successive partial images into one complete colored one. In addition, these successive processes have another disadvantage: they often show a colored fringe around the edges of a moving object. This is natural, for, in the simple case of, say,

a hand in motion, it could hardly be expected that the red image, having been taken a fraction of a second after the green one, would show that hand in exactly the same position. Obviously, if the two were super-

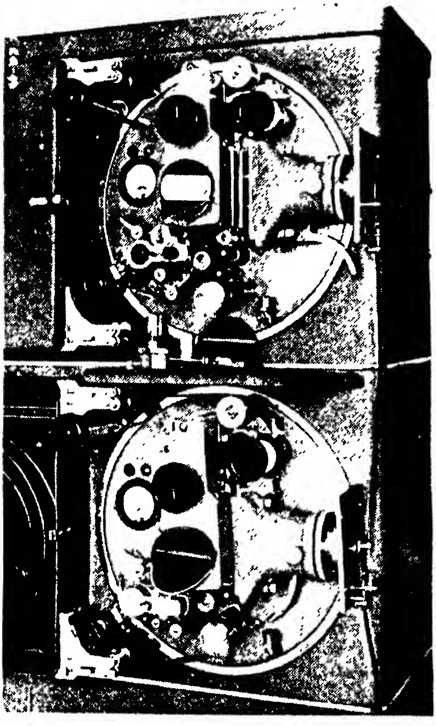


FIG 36G

imposed one on the other, they would be a trifle out of register, and leave a tiny clear space around the edges of the hand. On the screen, then, one of those clear spaces will be red, and the other green, giving to the eye the effect of a flickering red and green fringe around the hand during its movement. On the other hand, simultaneous images, whether projected from seperate films, as in some systems, or by a multiple lens arrangement, as in others, naturally require a lot of extra apparatus, which is a serious drawback,

commercially. Incidentally, if separate films are used, the problems of maintaining exact register assumes unpleasant proportions.

All in all, the problems of color cinematography are so numerous that it is a great credit to the many individual experimenters that the matter has been brought to its present successful stage, where films in color are not only practical for professional use, but available for amateurs as well.

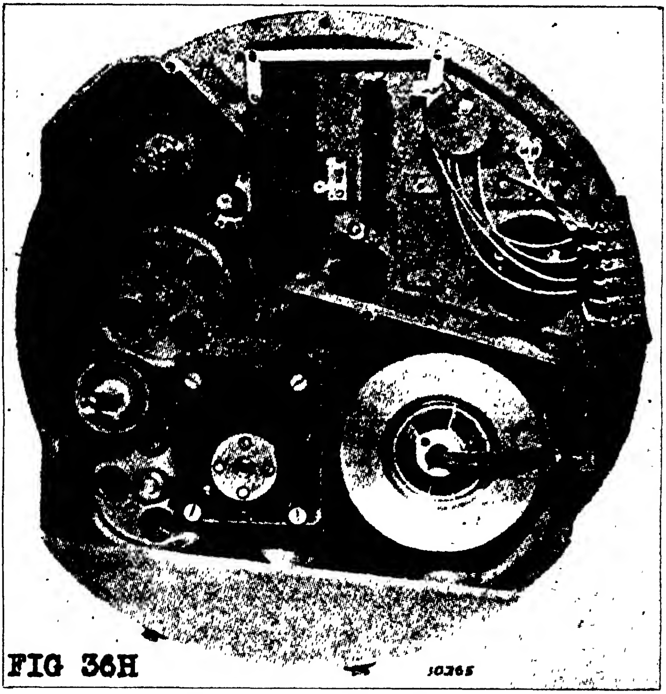


FIG 36H

KINEMACOLOR

The first commercially successful color films was Kinemacolor, while it had a short life in this country it netted millions abroad. Kinemacolor pictures had their first theater presentation at the Palace Theater in London, England, late in February 1909. The first showing in this country was in Madison Square Gar-

dens in December 1909, this showing was arranged in an attempt to sell the American rights. It was not until 1912-13 that the English built Kinemacolor projectors were installed in theaters of this country. The writer made the installations in the New York City theaters then owned by William Fox, and personally operated the first of these projectors, at the old Star Theater at 107th Street and Lexington Ave., in New York City. It was at this theater that instruction in the operation

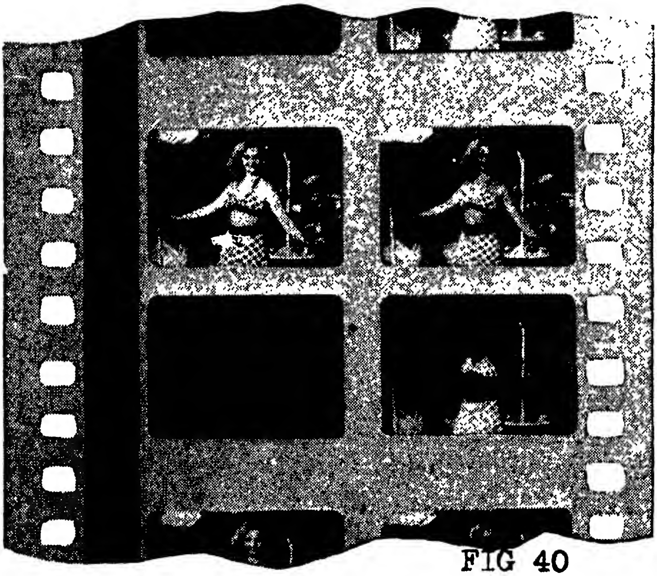


FIG 40

of these projectors was given operators who later were to operate the machines in other of the Fox Theaters.

In 1913, the days of the "silent" picture, film was run through projectors at the rate of 16 frames a second, with Kinemacolor, however, 32 frames a second had to pass the gate aperture, sixteen of these frames, each alternate picture, being projected through a blue-green light filter, while the other sixteen were projected through a red-orange light filter. This color filter was located between the light source and the film and was run in synchronism with the film so that the

evenly numbered frames were illuminated by the red-orange filter, while the odd numbered frames were illuminated by the blue-green filter. The color filter looked much like an enlarged two-wing shutter. The projector was motor driven, and as a matter of record, it was the introduction of the Kinemacolor projector that helped materially in having the laws then on the statute books of a great number of States and Cities against the use of motors on motion picture projectors rescinded.

These laws were intended as a fire prevention measure, it being feared that if projectors were electrically driven, the operators would leave their posts besides the running projectors and not be on hand in case of a film break or film fire. As it was practically impossible, however, to drive the Kinemacolor projector by hand, having to run just twice as fast as the black and white projectors, an exception to this specific law was made, and this in time proved to the authorities that fire risks were no greater with motor driven machines, than with the old hand cranked projector.

The operation of the Kinemacolor projector was noisy as old time operators will recall. The results on the screen in no way compared with the color pictures of today, the projected Kinemacolor picture was generally framed with a fringe of colors, made up of practically every color in the spectrum. The most pleasing of the colors were the various shades of brown.

Our only excuse in including the Kinemacolor projector in this chapter, is because of the fact that it was of special construction, that it was operated at just twice the rate of speed then standard for black and white projection; that it was the indirect means of recinding the laws against motor driven projectors, and because Kinemacolor was the first successful "natural" color process to reach the theater.

PROJECTION OF THOMASCOLOR PICTURES

The difference in the Thomascolor method lies entirely in the camera lens and in the projector lens. Standard black-and-white film is used for both pho-

tography and projection. The Thomascolor method is completely perfected, refined and adapted for use with standard motion picture equipment in photographic, laboratory and projection work. In all these departments the necessary original installation adaptations require but a few hours time at the most.

The Thomascolor projection lens is approximately the same size as an ordinary lens and has the same latitude of operation. Length of throw, size of picture, and focal length are changed with the same facility as with a standard lens. Focus adjustments may be made with the same comparative ease as with a regular lens. The Thomascolor lens requires no physical change in the projector equipment other than fitting. Once adapted to the machine it can easily be slipped in and out and replaced with a standard lens. The lens is completely optical and photographic and, therefore, does not involve the use of any moving parts.

The projectionist should approach the Thomascolor lens with confidence for he is already acquainted with the basic principles of its operation. It is, in fact, three lenses which are the same as to coverage, resolution, color correction and aberration. They are matched for focal length and image size. In other words, the three lenses are identical in every respect. They all will project identical images as to size upon the screen, and will transmit the same amount of light. All three lenses transmit and project light from the same source and they all focus to the same sharpness.

The Thomascolor patents cover a multiple element lens which may be made to project and superimpose a number of images. Although it is made as a four-element lens, under ordinary projecting conditions the three primary spectral colors are used and, consequently, only three of the lens elements come into use. For the sake of simplification, the Thomascolor process is described here as a three-color process and the lens as a three-color lens.

The motion picture film used in the projection of Thomascolor is the same in every respect as the

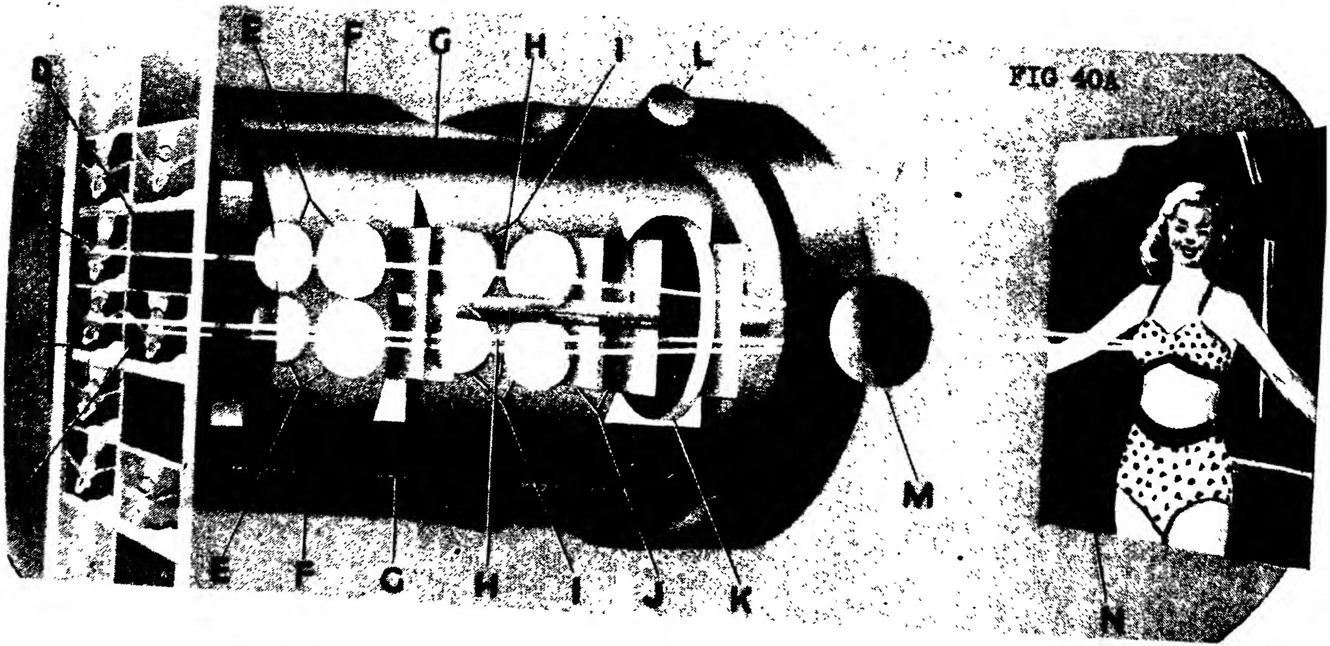


FIG 404

standard film except that in place of each single 35-mm frame, there are three frames a little larger than 16-mm in each 35-mm space, and one blank unphotographed frame. These three diminutive frames are identical as to frame and image size. They differ one from the other only in their color record.

Looking from the projector light source through a single 35-mm frame, there appears on the left of the projector aperture two identical frames, slightly larger than 16-mm. On the right and at the bottom appears a single slightly larger than 16-mm frame with an opaque blank above it. The frame in the upper left corner is a record of the blue light from the photographed subject, the lower left is a record of the green light from the subject, and the lower right is a record of the red light from the same source. When these three images are projected on the screen simultaneously and in register, the result is a full natural color picture of the subject.

Since each of the three frames is photographed through a different color filter, each frame is a record of one of the primary colors of the solor spectrum—either red, green or blue-violet. Filters are of the same color in both the camera and projector. Each frame is projected through the same color used in photographing. For instance, the frame photographed through the red filter is, in turn, projected through a red filter.

In effect, this is what happens in taking and projecting a Thomascolor picture. The camera takes the picture apart and records each color separately. The projector then reassembles the picture on the screen in full natural color

On the projection frame which carries the record of the red light which comes from the photographed object, all the full red tones appear transparent on the film, thus allowing the light to pass through without interference. As the amount of red in a particular part of the picture diminishes, the tone on the film becomes more opaque or blacker, allowing less

of that color to pass through the lens system and reach the screen. Thus, ranging from complete transparency to total opacity (or blackness), all the intensities or red is true of the other two primary colors.

It might be explained here that the primary colors of projected light are exactly the opposite, or complementary, of the primary colors of pigments. We learned at school that in mixing colors in a paint box we used red (a magenta red, not an orange red), yellow, and blue (cyan or peacock blue) as a basis for all the colors with which we are familiar.

In Thomascolor, or projected light, the spectral primaries are used. These are red, green, and blue-violet light. These three colors may be mixed in innumerable ways, giving us all the different hues, tints, and shades. Thus, red and green light in equal amounts will result in a yellow light; combining red and blue-violet light gives a magenta light; green and blue-violet light will produce cyan or blue light. A pure white light is obtained by combining green, red, and blue-violet lights.

In projecting the picture on the screen, let us consider first what happens from the standpoint of the red frame only. The light passes through the image in the lower right corner of the film, which we know is the red record. It passes the film only in those places and to the same degree as the light which came from the object photographed.

Where the object was totally red, the film appears transparent. As the red in the object diminishes the film becomes darker, thus cutting off the amount of light allowed to pass through the red lens system. In places where the film is totally black the light is completely cut off and no light is allowed to reach the screen from this point on the frame. Consequently, none of that color reaches the screen at that point.

The light then leaves the film plane and enters a rear element which conducts it to the red lens system. Leaving the lens system, the light passes through a red filter which colors the image. It is then pro-

jected on the screen where, viewed separately, it would appear as a red picture of the object with many of the details incomplete or totally missing. Only those parts of the object colored red would appear on the screen, and only to the degree in which the color was present.

The same succession of incidents is occurring at the same time to the light coming from the green and the blue-violet frames. As the three images come to focus on the screen, *and only on the screen,* they are brought together, or registered. The superimposition or register is perfect, without a trace of color fringing of any kind. The result is a beautiful picture in full natural color, in perfect register and sharp focus.

The register of the three-picture images is made possible by moving all three lenses toward a fixed point at the same time and to the same degree. This movement is simultaneous and the process of movement is called synchronization.

Registration can be effected while the projector is in operation and with the same facility as with a regular lens. This is done by means of a knurled knob on the side of the Thomascolor projector lens which causes the three lens system to move in unison. The superimposition is automatic and infallible. The register is set, of course, at the time of installation. The lens is installed, adjusted and tested. Fig. 40 shows an enlarged section of Thomascolor positive film. On the left of the film is the sound track. The upper left is the red projection frame; the lower left is blank and used for special effects and other purposes; upper right is the green frame, and the lower right is the blue-violet frame.

It should not be necessary to readjust the lens except in an emergency, such as the stretching or shrinking of film. In such cases, a slight turn of the knob will put the picture back in register. Due to the fact that stretching or shrinking is uniform over the entire surface of the film, frames and images always remain in the same relative position. Therefore, a skilled

projectionist can operate the Thomascolor lens with only a few minutes instruction.

It is not necessary to increase the amperage in order to show a Thomascolor picture. The Thomascolor lens can be substituted for the standard lens without increasing the light at its source. Prefocus is accomplished with a Thomascolor lens by means of an ingenious lens holder. Each Thomascolor and each standard lens to be used on a projector is mounted on a holder, put on the machine, brought to a focus and locked into position. The lens and its holder may then be removed from the projector as often as desired without disturbing the focus of the lens. The holders with the lenses mounted and in focus can be changed immediately.

The projector sound equipment is in no way disturbed. The sound track on the Thomascolor film is standard in every way, and its function, control and adjustment remains the same.

The illustration Fig. 40A is a diagram of the Thomascolor lens in operation: (A) red projection frame; (B) green projection frame; (C) blue-violet projection frame; (D) blank frame special purpose use; (E) rear lens elements; (F) Thomascolor lens holder; (G) Thomascolor lens (H) Light paths; (I) front lens elements; (J) color filters; (K) critical focus adjustment; (L) lock screw to lock Thomascolor lens in place in holder after it has been put into pre-focus adjustment; (M) register screw for bringing images into super-imposition on the screen, and (N) Thomascolor picture on the projection screen in full natural color.

TECHNICOLOR PROJECTION

The projection of color film like Technicolor, calls for no special projecting equipment, these films may be run on any standard projector, however, there are one or two points to be watched when using Technicolor prints if maximum screen results are to be obtained. It will be noticed that when projecting a Technicolor print, after projecting a black and white sub-

ject, that the objective lens has to be re-focused. This "out of focus" effect has to be especially closely watched where both Technicolor and black and white subjects are mounted on the same reel. Check your focus when you switch from Technicolor to black and white.

A considerable loss in color values takes place when Technicolor pictures are projected using a Mazda lamp as the light source, especially at the blue end of the spectrum. Technicolor prints are balanced for, and inspected in the studio by, a high-intensity light, however, satisfactory screen results and color renderation can be obtained with practically any arc-light source. Herewith is a copy of the instructions sent out to projectionists showing the Technicolor print of *Gone With The Wind*, these instructions can be profitably followed in the showing of any Technicolor print.

Since the production is made in Technicolor, a minimum amount of light should be used in the auditorium proper. During the continuous performance, where people will move in and out, it will be necessary to have sufficient illumination in order that such movements can be made in safety. It is therefore suggested that the auditorium lighting be of blue. This blue lighting should be of sufficient glow only to insure safety in the movements of patrons.

Plus this blue lighting, the aisle and step lights should be utilized and of course, the exit lights. The latter, where local ordinance permits, should be in green. No reds or ambers, except where the law requires, should be used for lighting of the auditorium in the showing of this production.

Extra care should be taken that no glaring lights, such as side wall brackets, *etc.*, strike the eye, as this will serve to interfere with the proper color effect of Technicolor. Particular care should be taken where side boxes are in use, that all lights to the entrances of these boxes should be masked, either by the box curtains, or some other method that will prevent the glare of same into the patrons' eyes.

It is requested that especial care should be taken to

see that no light, especially colored light, is projected onto the screen, screen masking or stage proscenium prior to, or during the showing of the picture.

Please do not have any screen masking or stage proscenium lights even during the main title, as this also

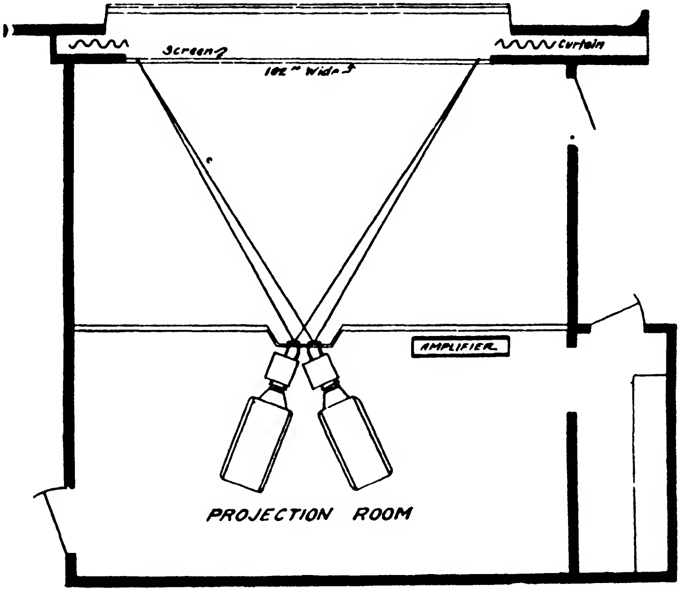


Fig. 41

has been designed with great care and at great expense.

The mechanism, sound heads, magazines, and fire valves, should be kept extremely clean at all times. The use of a cloth on all these parts, after each reel, will insure clean projection throughout the engagement and add to the elimination of possible scratching.

This is the latest type of Technicolor and it will be found that an excellent focus can be maintained at all times, providing, of course, that the projection lenses and arc condensers are kept in a clean condition. The faithful reproduction of this picture onto the screen depends upon the diligence of the projectionist and we are confident that they will cooperate to the fullest

extent.

It is recommended that at least one week prior to the showing of this picture, that your sound equipment be given a thorough inspection by your service engineer and necessary corrections be made in order that the ultimate in reproduction may be obtained.

It is suggested that the necessary volume for dialog be set in accordance with the requirements of the auditorium. Once the proper dialog volume is set, no other changes will be necessary, as the recording has already provided for changes in volume for sound effects and music. Therefore, when your auditorium dialog is set properly, the affects and music will automatically increase in volume in accordance with the dramatic effects desired by the producer.

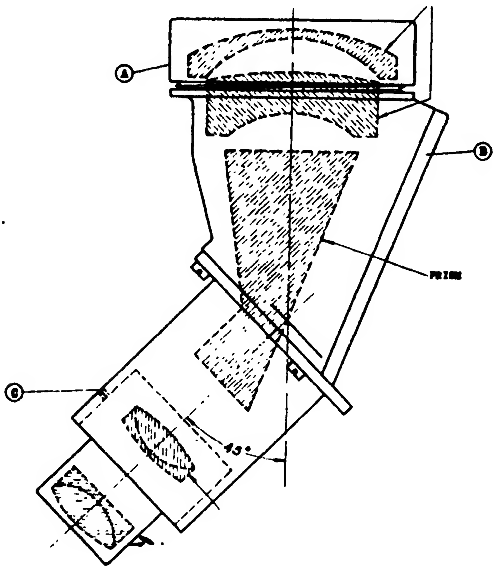


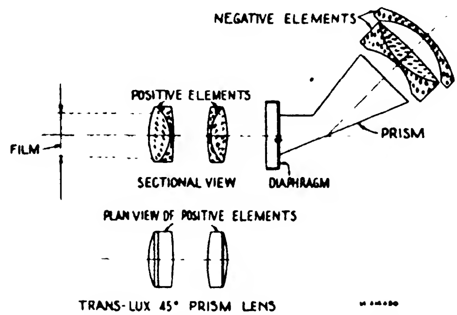
Fig. 43

REAR STAGE PROJECTION, TRANS-LUX

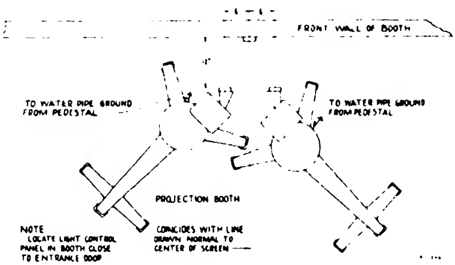
The projecting of pictures from behind the screen until the operation of the Newsreel Theaters, where lack of space made the practice necessary, was a novelty in this country, however the practice has been quite common in Europe for many years past, as a matter of

record, Lumiere used rear projection in the early 1900's. The success of rear stage projection in this country is directly responsible to the efforts of the Trans-Lux Corporation, operators of small Newsreel Theaters.

The locating of the projectors behind the picture screen carried with it certain obvious difficulties. The distance from the projection lens to the screen was



Elements of Trans-Lux Projection Lens



Relative Position of Projectors in Trans-Lux System

essentially large, requiring considerable depth back stage, with a consequent increase in the cost of theater construction. The use of a wide angle projection lens and short throw resulted in the appearance of a "hot spot" or round area of white light in the center of the picture screen. This, of course, was extremely objectionable.

In addition, the film had to be reversed when threading the projector, a problem fraught with considerable difficulty in that with the advent of sound-on-film, the reversal placed the sound track on the side of the film opposite to that which it normally occupies. This necessitated a rebuilding of sound head equipment.

The projectors are located directly behind the picture screen, and not at a point off-stage as some speculatively minded individuals will have it. The distance from the projection lens to the back of the screen is eight feet. This amazingly short throw is made possible by means of a special lens system. The projectors and sound heads are threaded in the standard way, no reversal of the film being necessary. Reversal of the image on the picture screen is accomplished by means of a reflecting surface which forms a part of the lens system.

With respect to the position of the projectors, it may be said that they are set in such a manner as to form a forty-five degree angle, the forward end of the projectors forming the apex of the angle. As is shown in the Diagram Fig. 41

The distance from the screen to the back wall of the stage averages thirteen and one-half feet. The projection room is large in every instance, and there is no suggestion of cramping. The loudspeaker baffles are located below and very close to the bottom of the picture screen. This arrangement affords excellent illusion.

The operation of the equipment is simplicity itself. There is no difficulty in focussing, it being entirely practicable to conduct the procedure from the projection booth, although it is customary to have someone at the front of the screen as a double check on the crispness and clarity of the picture. An interesting observation which may be made at this point is the fact that from the projection room the picture titles appear reversed on the picture screen. This occasions no real difficulty, however, as it requires but an amazingly short time to become adept at reading the captions from right to left.

The optical principle involved in the rear projection

lens may be explained in this simplified way:

The lens consists of three main optical units (See Fig. 43) calculated in relation to each other and combined to produce the desired results. The odd shape of the lens is due to the first of these units, which consists of

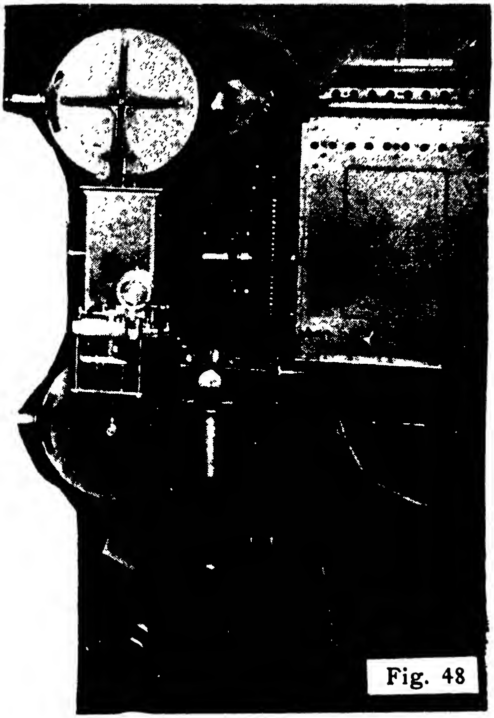


Fig. 48

a specially designed reflecting prism which bends the light through an angle of about 45°. This accomplishes two purposes; namely, the placing of the projectors close enough to each other so that the pictures will coincide on the screen without keystone or distortion, and the reversal of the picture so that the titles read correctly from the auditorium.

This latter feature eliminates the necessity of reversing the soundheads of the projectors and permits the use of standard projectors and soundheads and the threading of the film in the normal way. This prism is

unsilvered so that the loss of light is, theoretically, not over 10%. It is placed between the other units of the lens.

The second unit consists of what might be considered an ordinary positive projection lens, except that it will not project a satisfactory picture when used alone and is intentionally calculated that way in order to produce the required result in conjunction with the other units. It consists of two achromatic positive lenses spaced apart a fixed distance, mounted in a single barrel, and having a focal length of approximately 3 inches.

The third unit consists of two negative lenses, one of them achromatic, spaced apart a fixed distance, which is relatively small, and forming a negative combination. When the negative unit is placed in front of the positive unit, the beam of light is suddenly spread out, forming the picture at a distance less than one-third the distance required by the positive unit above.

VIVATARG SOUND CONTROLLED PROJECTOR

This was a projector whose operation, starting, stopping and re-starting was controlled by sound waves. It contained many innovations, it used a water cooling condenser, much like the spherical glass flask first used in the Lumiere projector. This water cooling condenser was necessary due to the fact that the use of the projector called for the film to be held stationary in the gate aperture while being projected onto the screen, for a much greater period of time than is necessary in ordinary projectors. The projector was motor driven, but the driving agent could be instantly automatically disengaged by means of a relay which was in turn acted upon by sound waves.

The projector was first installed in this country in a "shooting gallery" in the basement of the Strand Theater on Broadway, New York City. The projector and associated equipment was installed in a booth, this booth being sunk in the floor, so that the top of the booth was just under a counter, about waist high from the floor, that ran across the room, and on which the

rifles were laid and on which the marksman could rest while taking aim at the motion picture.

Some thirty feet away, directly in front of this counter, was a large paper screen on which the pictures were projected. Special film subjects, such as a rabbit running across a field, or birds in flight were projected to test the marksman's aim. The idea was to have the customer shoot at the desired object in the motion picture, the report of his rifle, would automatically stop the projector, leaving the frame of film

Fig. 49

stationary on the screen for a pre-determined length of time. the bullet would penetrate the paper screen on which the pictures were projected and a light,, placed behind the screen would show through this hole, and show the customer just how close he had come to hitting the moving object aimed at . The pro-

jector was so adjusted that when it came to rest, the rotating shutter blade was clear of the objective lens.

The sound of the report from the rifle was picked up by one or two telephone receivers which were mounted just above the marksman's head, these were

Fig. 51

fitted with a horn arrangement and looked much like the old type speakers used in the early days of radio. The sound picked up by these receivers actuated a relay, which in turn operated a clutch arrangement which disengaged the projector mechanism from the

driving motor, thus leaving the film stationary. After a period of time, which gave the marksman an opportunity to see where his shot had registered, the clutch again engaged with the projector mechanism and the picture on the screen resumed motion. The length of time the picture stood still on the screen, was predetermined and preset. The make and break contact, used in stopping the projector and re-starting it was a simple affair, the sound waves actuated a relay, which in turn operated a metal rod plunger, this plunger working in a cylinder of oil. On the report of the gun this metal rod was plunged down into the oil,

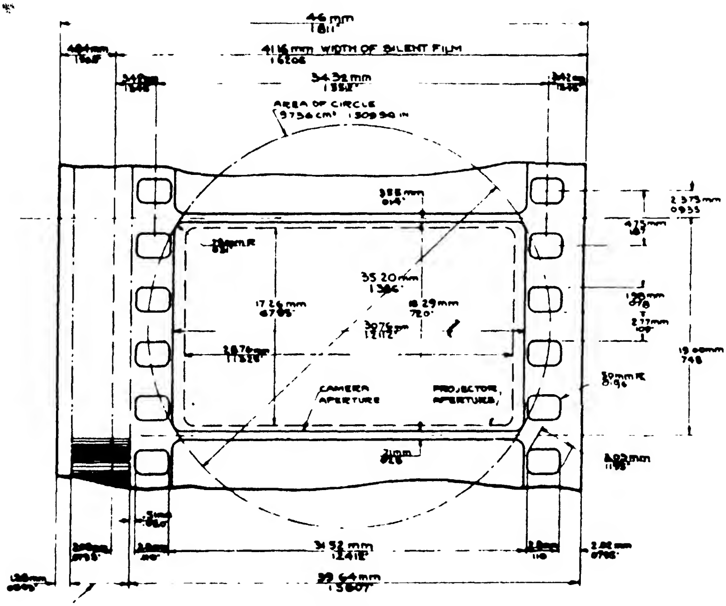


Fig. 52

thus breaking contact and stopping the projector. The electrical circuit remained open until the metal plunger worked its way back through the oil to again make contact and close the electrical circuit. The time it took the plunger to work its way back up through the oil represented the time the picture remained stationary on the screen. This time could be either

lengthened or shortened by changing the consistency of the oil in the cylinder, the lighter the consistency the shorter the period of time.

As the top of the metal rod plunger again made contact with the top of the oil cylinder, this would re-start the projector, and also would operate a relay attached to the screen take-up roller, which we will now describe.

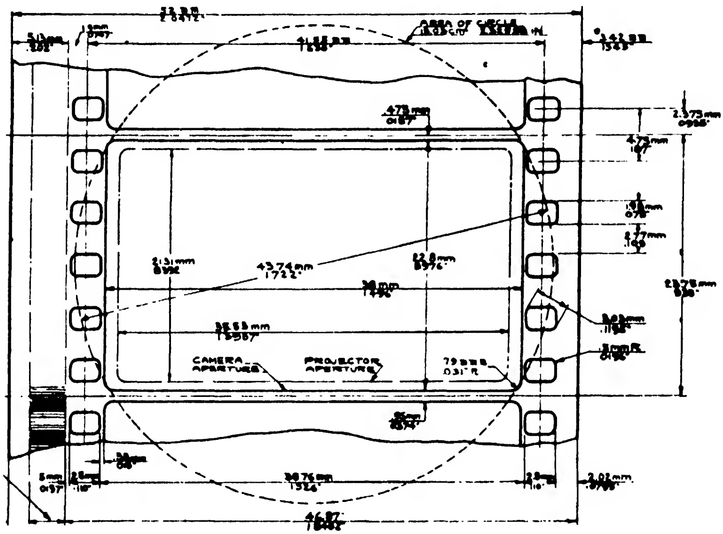


Fig. 53

The screen was a paper one, at least two layers of paper being used, it measured approximately eight by ten feet. A large roll of paper, much like the rolls of paper seen on trucks on way to newspaper print shops, was placed on end, in suitable supports, at one side of stage, the end of the paper was drawn off, and across the stage, where it was wound around an idler roller, and then the end was drawn back across the stage and attached to the take-up roller. It will thus be seen that we have two layers of paper making up the screen, the front sheet running from left to right across the stage, the back sheet running from right

to left across the stage. The two layers were held in close contact, so there was no space between them.

The customer took aim at the picture being projected on to this screen, his bullet passed through two layers of paper, the hole made by the bullet, showing up as a spot of light, as the picture on the

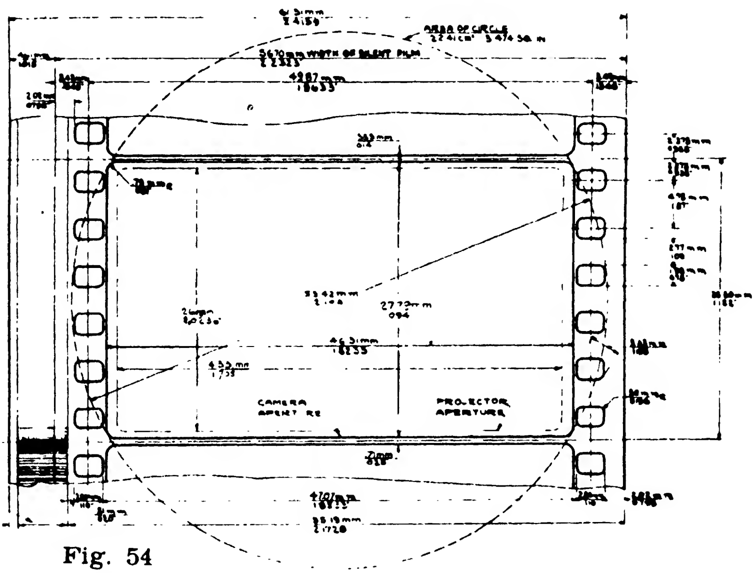


Fig. 54

screen resumed motion, the relay on the take-up roller on which the paper screen is attached, turns the roller about one-eighth of an inch, thus the paper nearest the marksman travels one-eighth of an inch to the right and the second layer of paper travels one-eighth of an inch to the left, this closes the hole made by the bullet and gives the marksman a clean unperforated surface to again shoot at.

In the construction of the projector, four obstacles had to be overcome, 1, to stop the picture instantly on the report of the gun. 2, to hold the picture stationary on the screen for any desired period. 3, to prevent the film from catching fire while stationary

in the gate of projector, and 4, to synchronize the rotating light shutter so that it would be clear of the objective lens when the projector stopped. Once the projector was started, it required no manual attention, it started, stopped, and re-started automatically.

Figure 48 shows a view of the Vivatarg projector, the special clutch attachment can be seen immediately above the lower magazine, and the water cooling system on the front of the lamphouse, Fig. 49 is the panel containing the controls and the relays for automatically starting and stopping the projector and for operating the travel of the motion picture screen. The "instructor" shown in Fig. 49 is the writer, this photograph having been made in 1917, during the first world war, when we were engaged in teaching projection to men in the service who were going overseas to operate projection equipment for American and Canadian soldiers.

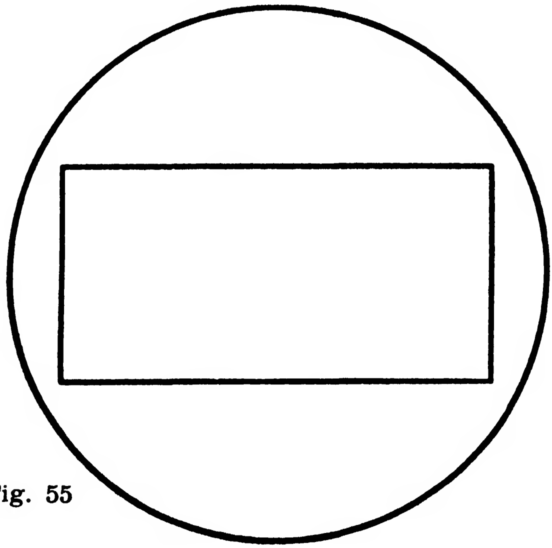


Fig. 55

WIDE FILM PROJECTORS

By wide film, we refer to film wider that the 35 mm. product, now recognized as standard. The use of wide

film dates back to the early days of motion pictures, in those early days, development of wide film and wide film projectors was not due to any desire on the part of inventors to give us a superior screen picture, but rather to circumvent any then existing patents covering the use of both film and projectors.

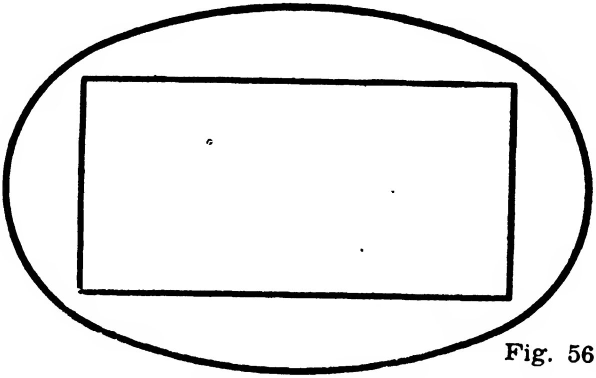


Fig. 56

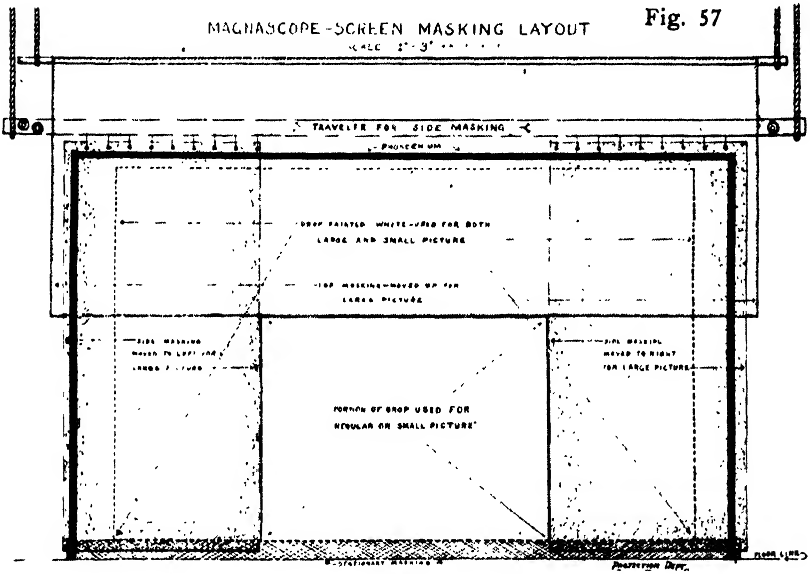
One of the earliest records covering the use of wide film, was in making the pictures of the Corbett-Fitzsimmons fight at Carson City, Nevada, on March 17th, 1897. The illustration at Fig. 51 shows a single frame of this picture, with the film perforations removed, from this it will be seen that the film picture is just twice as wide as it is high. These pictures were made on a special built camera, and this camera was later used to project the pictures at the Academy of Music in 14th Street New York City.

It was not until the early 1900's that the present 35 mm. standard was generally accepted, this was the size originally adopted by Edison and Lumiere. When sound was introduced in 1928, it was necessary to devote part of the space heretofore used for the photographic image for photographically recording the sound, and several producers started experimenting with film wider than 35 mm.

Several dimensions, all exceeding the standard 35 mm. were proposed, each producer having his own ideas as to what would constitute the ideal size. At one

of the conventions of the Society of Motion Picture Engineers, the Bell & Howell Company presented a paper covering suggested sizes, Figs. 52, 53, 54, show three of the proposed wide film sizes. From these diagrams it will be seen that the size proposed in Fig. 53 called for five sprocket holes to a frame, while Fig. 54 shows that six sprocket holes to each frame would be necessary.

Fig. 57

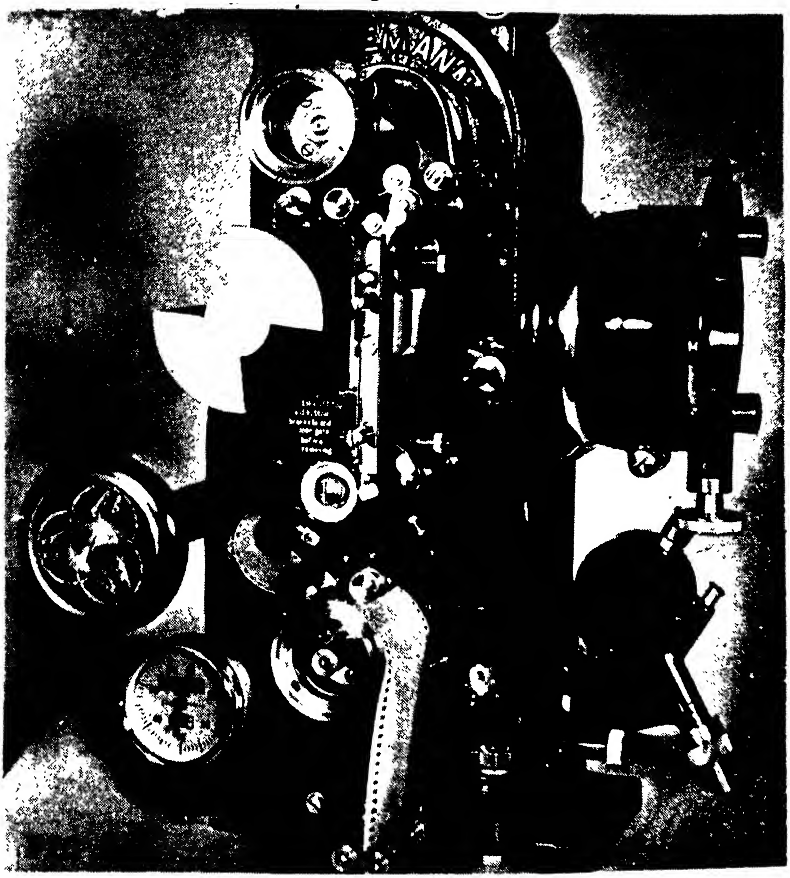


PARAMOUNT WIDE FILM

During 1929 and 1930 Paramount was working with both a 65-mm width and a 56-mm film. The standard film perforations were retained, but five sprocket holes instead of the customary four, were used to each frame of film. The camera used in filming these wide film subjects had an adjustible shutter opening of 230 degrees maximum.

A photograph of the combination projector used by Paramount is illustrated in Fig. 54A, this is a view of the right-hand side of the projector, with the housing removed. In the illustration the projector is thread-

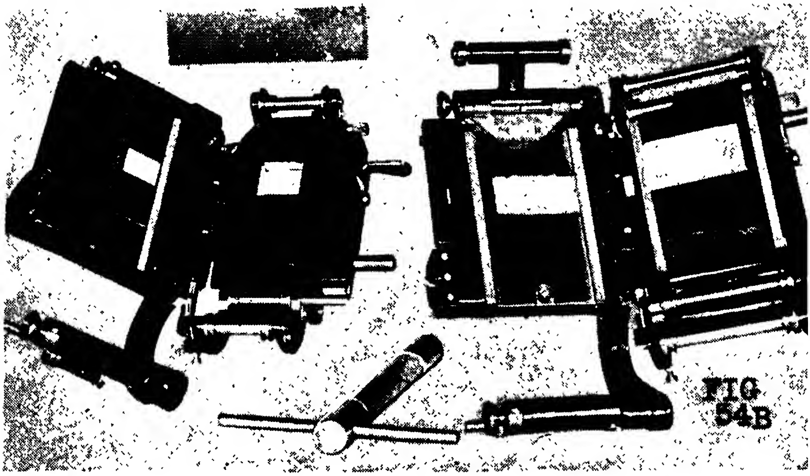
ed with 65-mm film. Fig. 54B shows two film gates for the projector, these were interchangeable, one being used for 65-mm film the other for 35-mm standard width film. Naturally a double sprocket had also to be used with the 65-mm gate.



GRANDEUR PROJECTORS

Grandeur was the trade name given by Fox to the wide film introduced by them. The film was 70 mm wide, while the frame was 22¼x48 mm, which left a sound track space 7 mm wide. The film was manufactured by Eastman Kodak, and being just twice the width

of standard film, it cost just twice as much. The camera used in making the pictures was built by Mitchell Camera Corp., this was a standard moving picture camera, with the film track enlarged to accommodate the wider films. The gears were somewhat differently cut due to the change in pitch of the film perforations, and the camera shutter, had of course, to be greatly



enlarged. The camera, too, had to employ special lenses.

The Grandeur Projector was built by the International Projector Corporation, the projector used at the Gaiety Theater on Broadway, New York City, where the first commercial showing of Grandeur was given, was a hand built model, the projector weighing over 1,600 lbs., the film came 2,000 feet on a reel that weighed 35 lbs. The light source was a high-intensity arc, operating at 150 amperes. The Grandeur Projector used a rear rotating light shutter, with two blades, one running in a clock-wise direction while the other blade ran in a counter clock-wise direction, the edges of the two blades meeting at the exact center of the film aperture.

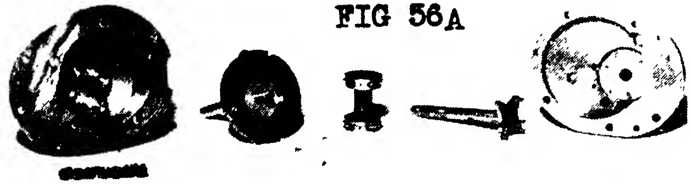
The Grandeur pictures at the Gaiety Theater were projected on a screen 35 feet wide and 17½ feet high, this was the limit in size possible due to the size of the

theater proscenium arch. The throw was 70 feet.

A special optical system was used, which we believe was designed by Bausch & Lomb Co. of Rochester, N. Y.

In using any film with a width of approximately twice the size of the height, a special designed con-

FIG 56A



densing system is necessary if a serious loss of light at the aperture is to be avoided. With an ordinary condenser combination throwing a round spot on the aperture, as in Fig. 55, the loss of light would, as can be seen, be a serious matter, this loss could be materially

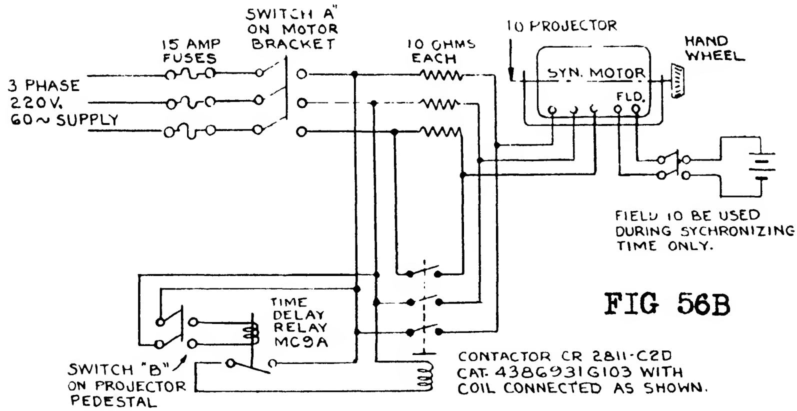


FIG 56B

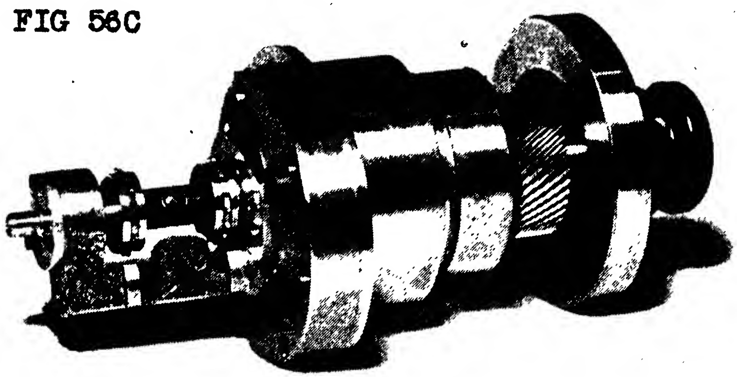
reduced by employing a condensing system which would give an elliptical spot of light, as in shown in Fig. 56.

The principle of Grandeur Pictures is not that of magnification, and should not be confused with the

Magnascope system perfected by Harry Rubin of Paramount. The Rubin Magnascope system can be understood by referring to the diagram Fig. 57.

The use of wide film, at least a film wider than the now standard 35 mm has a lot in its favor, the cameraman has much greater scope in his composition, and considerable advantages in his lighting, especially as regards top-lighting and back-lighting. Direction of ex-

FIG 56C



pansive scenes is greatly simplified. Sets do not have to be built so high. Scenes do not have to be "followed" as there is ample room in a normal long shot for all lateral movement used in most sequences. It offers advantages to the recording of sound, as the recorder would have a much wider sound-track to work with. The projected picture is more pleasing to the eye, this was the concensus of opinion of all those whom the writer contacted after the performance at the Gaiety Theater.

G. E. TELEVISION PROJECTOR

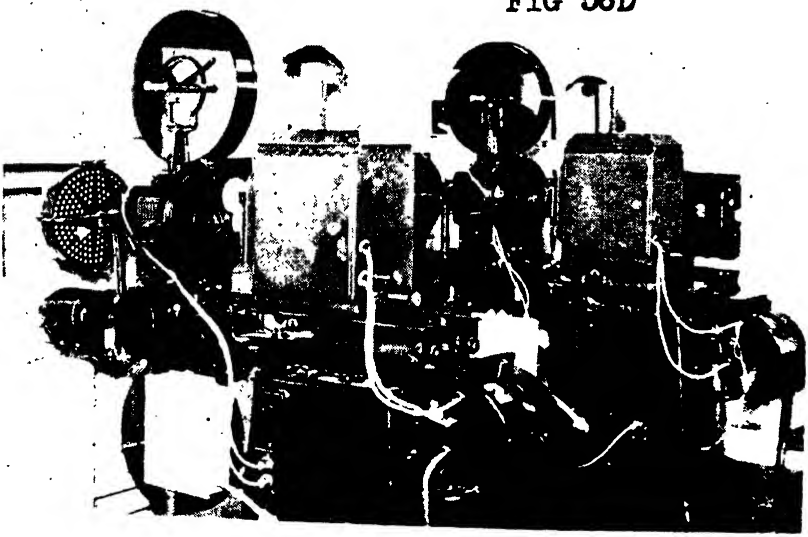
The General Electric Company decided to use the Simplex projector in the development of theater television, when they started this project in March 1938. The Simplex E-7 projector had of course to be modified greatly to suit the special condition peculiar to the

television field.

In the standard model of the Simplex E-7, the intermittent is so timed to project one frame of picture per revolution, thus, the drive shaft normally revolves at 1440 rpm, so the standard form of Geneva movement intermittent could not be employed for television, and a new type of intermittent had to be designed, the disassembled intermittent used in the General Electric television projector is shown in Fig. 56A.

In the modification a new shutter-shaft driving system had to be designed, and a direct drive from the main drive shaft to the shutter shaft was used in order to relieve the projector gears and stud shafts

FIG 56D



of the shutter load, and to reduce the possibility of excessive speed variation in the shutter motion, that would otherwise exist due to back-lash in the gear train.- These factors were found to be of considerable importance. Since the motor operates at 1,800 rpm, a two-to-one increase in speed was made necessary by the use of a 3600 rpm shutter. Other modifications had to be made, including the use of a longer focal length

lens than is ordinarily used, and this had to be used with a special adapter.

A three-phase 220-volt, self-synchronous motor was used, the motor was equipped with a d-c field winding of approximately 150 ampere turns per pole to automatically phase the projector with the supply system, and hence, the electrical impulses used to effect scan-

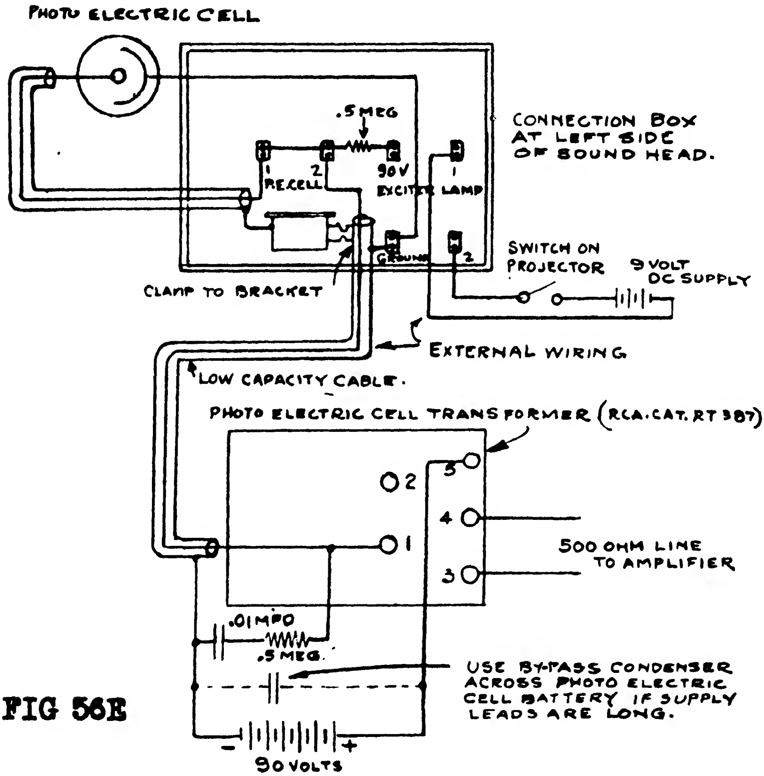


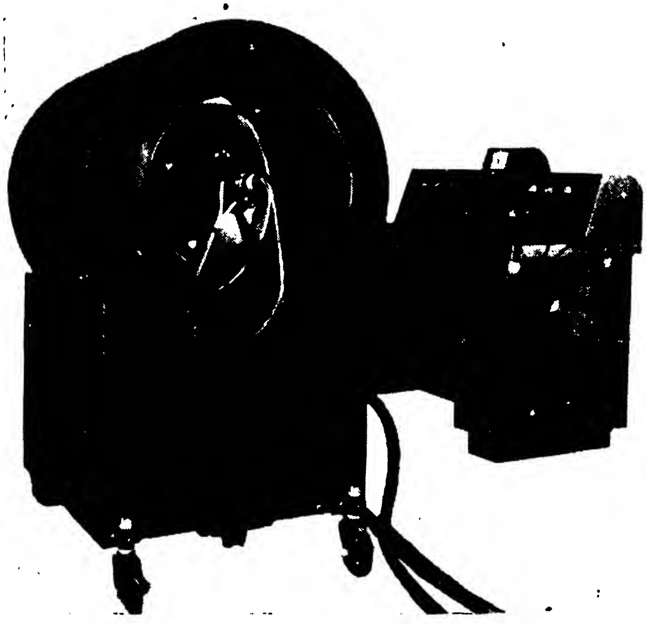
FIG 56E

ning. The soundhead used was the Simplex employing the Rotary Stabilizer, and utilizing a single stage of mechanical filtering to reduce the variations in film velocity at the sound scanning point to an acceptable amount. Fig. 56B shows the schematic connection diagram of motor starting circuit, Fig. 56C is the intermittent, while Fig. 56D the projection room at WRGB, schematic connection diagram is shown Fig. 56E.

R. C. A. TELEVISION PROJECTOR

Television has discarded the "scanning disc" in favor of the Iconoscope and the Kinescope, this bringing a new technique.

Basically, the Iconoscope is a vacuum tube in which is mounted a mosaic and an electron gun. The mosiac is a sheet of mica a few inches square, on which has been deposited millions of tiny particles of silver sensitized with caesium. Each particle is insulated from its neighbor by the mica between. On the other side of the mica plate is a metallic coating. The picture is focussed

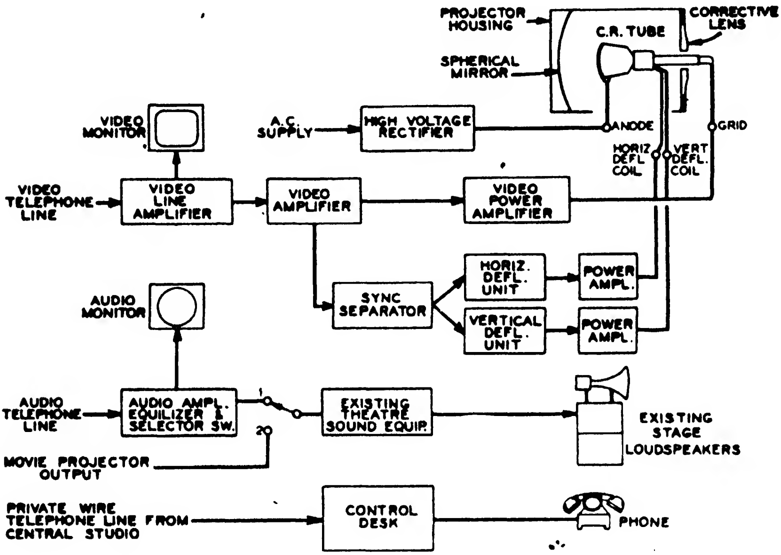


RCA theater television projector

on the front of the mosaic by a suitable lens.

The Kinescope too, is a vacuum tube containing an electron gun producing a sharp beam of electrons (or a cathode ray) and also a grid for controlling the intensity of the beam. On this grid is imposed a voltage proportional to the output current of the Iconoscope. If

the spot scanned in the Iconoscope is bright, the grid will permit many electrons to flow, on the other hand, if the spot is dark, the electron beam will dwindle. Thus the intensity of the beam is controlled in accordance with the light valves.



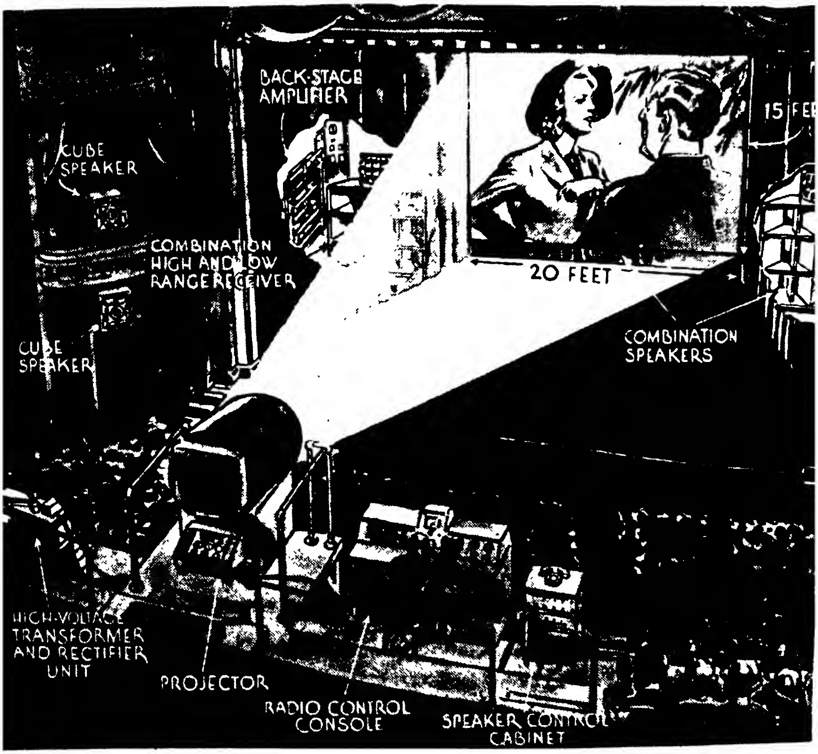
Block Schematic of Complete Theatre Television Equipment

The sound reproduction system used in connection with the theater television unit is of the extreme high fidelity type, similar in effect and arrangement to the Fantasound used in the motion picture "Fantasia," and explained elsewhere in this book. Differing from Fantasound in that it is manually controlled at the scene of reproduction, the multisonic system permits movement of sound with action on the screen, rotation of sound around the walls of the auditorium, and emanation of sound from any one desired point in the theater.

The large-screen theater television system operates on signals delivered to it either by coaxial cable or by special wire circuits.

The installation in the theater consists of three main units: control, power supply, and optical system.

The control panel gives the operator immediate handling of all controlling, metering, and deflecting elements. He can obtain at any time, every possible check on the operation of the system. Sharpness, brightness, contrast, and size of the image projected may be changed by the turn of a knob. The controls are so



simplified that the average motion picture projectionist could operate the unit with but slight training.

The second unit, the power supply for the optical or projection system, is a conventional high-voltage, rectifier rated at 70,000 volts. Normally, operation is at 60,000 volts.

The optical, or projection unit, is considered the most

important as well as the most complicated of the entire system. For purposes of description, it is possible to divide the unit into three principal elements; that is, the kinescope, or projection tube; the reflecting mirror, and the correcting lens.

The kinescope, built to handle high voltages, is similar in performance to the kinescope used in RCA's standard home-television receivers. The face or diameter of the tube is 7 inches; the tube's length is 14 inches. It is mounted in the center of a hollow steel-shielded cylinder 34 inches in diameter and 34 inches long. The face of the tube is pointed away from the stage screen, and the end of its neck pierces a small hole in the center of the correcting plate of the optical system.

The concave reflecting mirror, 30 inches in diameter, is mounted a few inches in front of the tube's face. The image on the face of the tube is picked up on the concave surface of the mirror, passed through the correcting lens and onto the screen with a magnification of 45 times. The lens corrects for aberrations and passes the image across the auditorium to the stage screen.

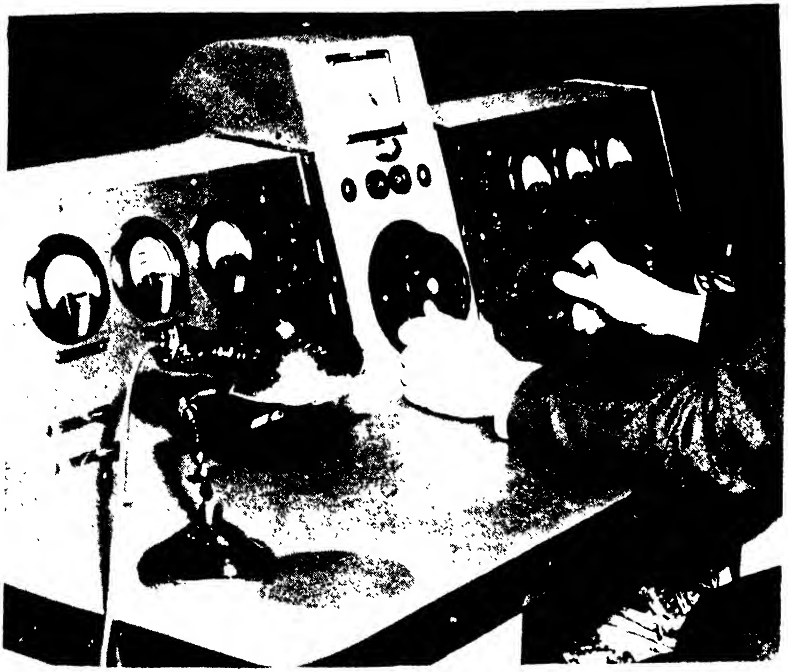
The optical system is unique in that it has a speed rating of f: 0.7, which surpasses the fastest known projection lens.

The optical unit housing is mounted on a pedestal which contains the video amplifiers and the deflecting output circuits. Because of the optical unit's high efficiency, the screen illumination obtainable in the system is adequate for large-screen pictures in theaters.

Controls for the sound, which accompanies the television projection, are mounted in a separate console, adjacent to the television control desk. They are linked to 18 high and low-frequency loudspeakers mounted around the auditorium. Wire lines connect the console with the NBC studios and with the central radio receiving point in Radio City. In addition, there are lines which the sound control engineers use for cueing the program.

Three banks of regular RCA Photophone speakers are set up on the stage near the screen. One bank is at

the rear of the screen, and the other two are at either side. Beginning at the outer edge of the proscenium arch, other loudspeakers are located at desired points along the side wall and in the rear of the auditorium. One large loudspeaker is suspended from the ceiling.



Television Projectionist at the Operating Console

The sound control engineer in the theater, taking his cue from engineers at the pick-up scene, is able to cause the sound to move from left to right or right to left, or to remain stationary in synchronization with the action on the screen. Whenever desirable, he can cause the sound to come from the left or right of the house, from the rear, and from above. Also, in effect, he can make the sound run around the house.

MOTION PICTURE ELECTRICITY

It is generally understood that matter is anything acted upon by gravity. Gases, liquids and solids constitute matter. Thus, liquid ammonia is a gas liquified in water, visible as a liquid, yet when spilled in a room, the ammonia gas is liberated, and in an invisible state fills the room with its odor. Thus matter may be visible or invisible.

No matter what the substance, solid or gas or liquid, it is composed of extremely small particles called molecules. The molecule is the smallest integral part of matter, regardless of its form. There are as many different kinds of molecules as there are different kinds of matter. Each substance is composed of molecules distinctly different from the molecules of some other substance. Each molecule in a substance is individual and separated from other molecules. Thus, there is a space between molecules and each is in a state of motion. It is general knowledge that when a solid is heated it expands. The expansion represents a change in the separation between the molecules. This item is of interest because it influences the performance of certain elements employed to carry electric currents. Under certain conditions representing molecular activity, certain elements will allow the free passage of electric currents, *i.e.*, offer very little resistance. Under other conditions, these elements will present a great deal of resistance to the flow of electric currents.

Molecules in solids are close together; in liquids further apart and in gases still more so. The proof is found in the substance itself. One is solid, the other flows whereas the third will mix with other gases such as air.

The Atom

We said that the molecule is the smallest integral part of any substance. We find that molecules in turn consist of small particles called atoms. The atom is the smallest particle of matter obtainable by any type of chemical action. Although it does not appear so at the present reading, there is a distinct difference between the atom and the molecule. The reader will note in a short while that while a molecule is individual, it does not necessarily consist of any one atom or any one type of atom. For example a molecule of water consists of two atoms of Hydrogen and one atom of Oxygen (H_2O). Whereas the formation of a molecule of the electrolyte used in a storage battery consists of two atoms of Hydrogen, one atom of Sulphur and four atoms of Oxygen. With respect to weight, atoms vary in weight and size, with the Hydrogen atom, which is the lightest of all atoms, being considered as the unit of weight. All other atoms are compared with the Hydrogen atom.

Electrons

According to a theory, the atom too, is a structure. Unlike the molecule, because certain gas molecules consist of but one atom, the atom consists of a minimum of two parts. One part, is called the nucleus, the other part is known as the electron. The nucleus is known to carry a positive charge whereas the electron is known to carry a negative charge. With respect to the absolute structure of an atom, general opinion is not uniform. As to the electron however, the consensus of opinion presents a very interesting point. The atom is material, whereas the electron is not. The latter is known as the smallest particle of negative electricity, and may exist when atoms are not present. Further, the electron as a particle of negative electricity is the same for all atoms no matter what the remaining structure of the atom. Hence all matter contains negative electricity and the electron of any one atom is the same as the electron of any other atom. The quantity of electricity carried by the electron is so small that it cannot be meas-

ured with any known device. This is in contrast to the fact that the size of an electron has been determined. Once again, while the atom may differ in weight and size, the electrons are always of the same size. The number of electrons in an atom are governed by the kind of atom, that is, the substance.

According to theory an atom also contains positive electricity, represented by the nucleus. Thus an atom consists of positive and negative electricity, and may be of three electrical states. One, when the positive charge equals the negative charge; two when the positive charge preponderates because an electron has been lost; three, when the negative charge preponderates because an extra electron has been attached to the atom. If the first mentioned state exists, the electron is electrostatically neutral and exerts no influence upon other atoms. If it is positive it exerts an influence upon electrons which have been detached from other atoms. Generally speaking only one electron may be detached from an atom. Hence, the normal atom, which we may term as being neutral presents no electrical properties.

It was stated that the electrical balance of an atom may be disturbed, at which time it will exhibit electrical properties. Such properties are the attracting force exerted upon other atoms or electrons. The disturbance of the structure of the atom may be of various forms. General agitation of the molecular structure of a substance will naturally agitate the atom and the electron. If an atom is caused to move and during the motion collides with sufficient force with another atom, an electron may be dislodged and the atom will then be shy an electron. Under such conditions, the atom will display electric properties representing a positive charge since its degree of electric balance has been disturbed. It now carries a preponderance of positive charges, and will continue to do so until by virtue of its attracting force upon other electrons, it has attracted another electron and again becomes neutral. In turn, an atom to which has been attracted an extra electron, will also exhibit electrical properties, but this time, repelling other electrons and easily parting with the extra electron. Thus we find that if we cause the agitation of the atomic structure

of a substance we will have a transient state of electrical properties. Whether the body will display a positive or a negative charge depends upon the structure, temperature, etc. . . . Upon the charge depends the action. Like charges will repel and unlike charges will attract.

Electric Field

If a body has a certain charge, either positive or negative and exerts an influence upon a neighboring body, be it repellent or attracting, that force which attracts or repels is naturally present within a certain distance of the charged body. The extent of this electric field is definitely limited. Experimental determinations show that the electric force between two small charged bodies varies inversely as the square of the distance. If the distance between two such charged bodies is increased twofold, the electric force is decreased to one-quarter of its original value. It has been determined that there is a difference of potential between two unequally charged bodies of opposite polarity. The plus (+) and minus (—) signs represent polarity. The former is positive and the latter negative. The difference in electric potential or electric force or electric pressure between two points in the electric field is a measure of the tendency of charges to flow or move from one body to the other or from one point to the other. If two bodies of equal potential are connected together with some medium such as wire, there will be no flow of electrons, hence the charges upon the bodies will remain unchanged. If, however, the two bodies are of different potential and they are connected by wire, electrons will flow from the body at the lower potential to the body of the higher potential until the two potentials are equal, which is the same as if the body of the higher potential had a lower positive charge. Assuming two non-uniformly charged bodies, the higher potential body is positive (+) and the lower body is negative (—).

Electromotive Force

If we develop a piece of apparatus which has two terminals

and the potential of one terminal is higher than the other, and we connect these two terminals with a piece of wire, we cause a movement of electrons from the terminal of lower potential, (—) to the terminal of higher potential (+). The source of electric force causes the flow of electrons as long as the circuit is complete. If this source is a battery, the chemical action within the unit creates the electric force, which makes the positive (+) side of higher potential than the minus (—) side and causes the electronic flow. Thus the battery creates an "electromotive force" and if we refer to the preceding paragraph, a difference of potential exists between the plus and minus terminals of the source of the electromotive force and also across the bar. Recognizing the flow of electrons in the circuit, each point in the circuit possesses some polarity with respect to some other point. Every point in the circuit is positive with respect to the minus terminal of the source of electric force.

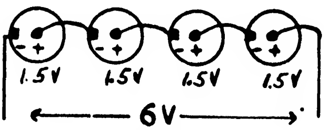


Fig. 65

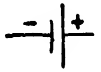


Fig. 63

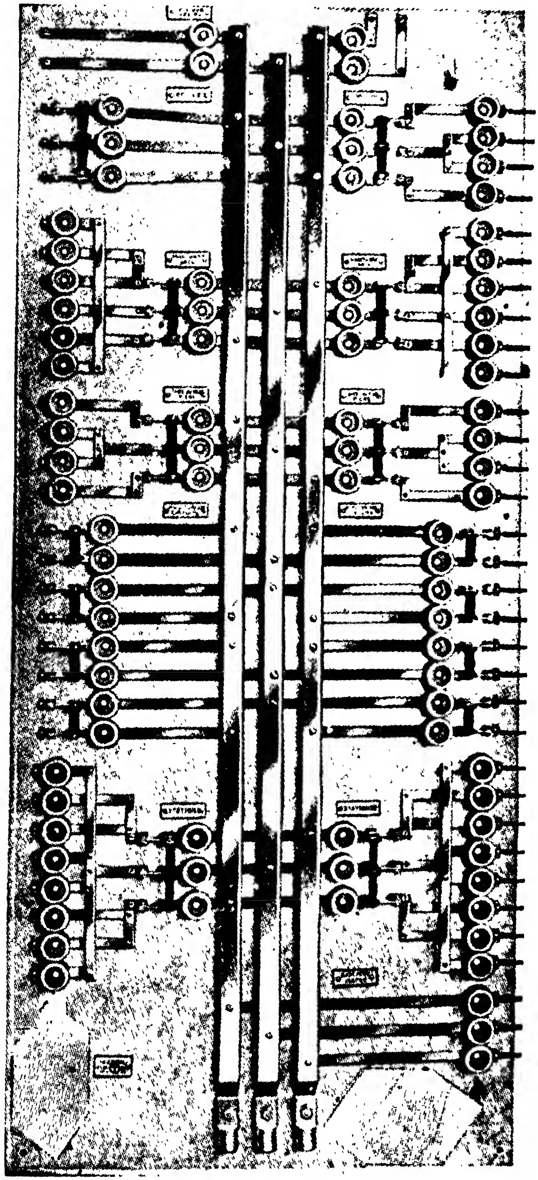
Fig. 64

Direction of Current Flow

We stated that the direction of the electronic flow in a conductor connected to a battery is from the negative to the positive pole of the battery. The direction of the electric current flow however, is assumed to be in the opposite direction, from the positive (+) to the negative (—) side of the battery. This assumption has been accepted despite the fact that the electrons are considered as constituting the electric current. Therefore when considering electric current we shall show the direction of flow from plus (+) to minus (—).

Conductors and Insulators

Mention has been made that electric current will flow when a conductor connects points of high and low potential. Quite



naturally the magnitude of current depends upon two factors; the force and the conductor. With respect to the latter we find good and poor conductors of electricity. Some offer little and others offer much resistance to the flow of current. The difference in conductivity is dependent upon the atomic structure of the conductor. We stated that electric current depends upon the ease with which an atom will part with an electron. We speak of an electronic drift in a conductor, which means that an electron moves from one atom to another. If an atom parts with an electron with relative ease, that substance is a good conductor of electricity. If however that substance is of such structure that the atom tenaciously holds its electrons that substance is a poor conductor of electricity. If conduction

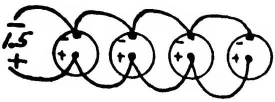


Fig. 66

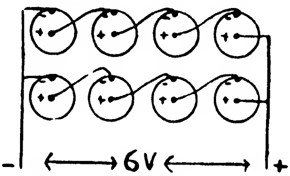


Fig. 67

is sufficiently low, the substance is known as an insulator. However certain insulators become good conductors under certain conditions. Glass for example at ordinary temperature is a good insulator, but when heated approaches a state of conductivity and when red hot is a good conductor. Dry wood is an insulator but when subject to moisture becomes a good conductor. Copper wire is a good conductor. The difference lies in the atomic action.

VOLTAGE

We know that electric current will flow through a conductor connecting two points of different electric potential. Whatever the type of device which creates the electric force required to cause the flow of electric current through a conductor, there exists across the positive and the negative poles of that device an instantaneous difference of potential. Whether this difference of potential is steady at one value or varies periodically is a matter of design. The unit of the potential difference is the "volt." It is at the same time the unit of electric pressure because a difference of potential represents electric pressure. Electric pressure, the volt is frequently referred to as "V" or "E." When it is a constant value the capital letter is employed, when it is an instantaneous value the small letter "e" is used.

From what has been mentioned, this unit is also applied when a difference of potential exists between two points in an electric circuit. Thus, while the magnitude of electric force, potential or electromotive force may be unity, some part of the circuit may be subject to a difference of potential which is not unity; instead a fraction. Hence the unit of electric pressure, the volt when expressed in numerical fashion may be less than or more than the unit value. When the value of voltage is a decimal of the unit, certain smaller units are employed. When the voltage in the system is some numerical value greater than unity, it is mentioned as a number such as 245 or 500 or 1,000. When its value of voltage is less than unity, frequent mention of the exact value rather than use of the prefix, is made, as for example .12 or .85 volt.

Method of Producing Electric Pressure

Electric pressure to cause the flow of current may be developed in various ways. As far as we are concerned, three such systems are of interest.

Chemical action, Thermal action, Induction.

The chemical arrangement is the battery, employed in various forms. Some are known as "dry" batteries and others are known as "wet" batteries. These terms are applied by virtue of the constituency of the battery. The essential parts of a battery are two dissimilar electrodes immersed in an electrolyte. The electrolyte is a solution of certain acids, salts in water or hydroxides, the exact constituency being a factor determined by the constructions of the battery. It might be well to mention at this time that there is a distinct difference between a cell and a battery. The latter consists of a number of cells, although it is common practice to refer to a cell as a battery.

Batteries are of two types, allied with construction and elements employed. These types are the "primary" and the "secondary." Primary cells are those which cannot be restored to active service once they have completed their operating life. Secondary cells on the other hand can be rejuvenated by means of electric current charges. This classification of cells is popularly known as storage batteries or accumulator batteries. The difference between the primary and secondary cell with respect to "charging" is found in the chemical action involved during the production of the electric force. When the primary cell is exhausted, it is necessary to replace the electrodes and the electrolyte. This is seldom done.

Storage Batteries

The storage battery on the other hand converts chemical action into electrical energy in a manner which is reversible, so that after the battery is run down (discharged) it is possible to cause the flow of electric current through the cell in the direction opposite to the flow of normal operation and thus reverse the chemical action.

The battery consists of a number of cells. Each cell in turn, consists of lead plates immersed in a solution of sulphuric acid and water. The plates are constructed in the form of grids, and consist of an alloy of lead and antimony. Into each of the grid openings is placed a paste made of lead oxides.

Then the plates are passed through a process of oxidation by means of electric current, so that the paste material becomes lead peroxide. These plates are the positive plates, and bear the + designation. The negative plates are changed from the oxide condition of the paste to sponge lead. A number of positive plates are fastened to a supporting member and a terminal fastened to the group. The same is done for the negative plates and groups of positive and negative plates are then arranged to interleave, with thin wood separators between them to prevent direct metallic contact. Each such group contains one negative plate more than the number of positive plates and each group constitutes a cell. Several such cells are then connected to form a complete battery.

When the battery is placed into operation, it is said to be discharging. During this process it is thought that the sulphuric acid in the electrolyte combines with the sponge lead, of the negative plate and with the lead peroxide of the positive plate, forming lead sulphate in both cases. This process of combination converts chemical action into electrical energy. When the battery is placed on charge, the electric current passed through the battery reverses the process present during discharge, *i.e.*, removes the sulphuric acid which has combined with the sponge lead and the lead peroxide and it is transferred back into the electrolyte. Thus, electrical energy is converted into chemical energy. When the cell is completely charged, all of the acid has been returned to the electrolyte.

Dry Batteries

With respect to the dry type of battery, the electrolyte is held in an absorbent material, which enable utility of the battery in any position. One electrode is the container itself made of zinc. The other electrode is a mixture of ground carbon and manganese dioxide. The electrolyte is generally a solution of ammonium chloride and zinc chloride. The ground-carbon manganese-dioxide terminal is the positive pole and the zinc container is the negative pole. Connection to the positive pole is accomplished by a clip fastened to a carbon

rod imbedded in the ground-carbon manganese-dioxide mass. During the process of discharge the zinc is eaten away.

Another type of dry-cell is the silver chloride unit. The positive electrode is silver and the negative electrode is zinc.

A battery, as was mentioned consists of a number of cells. Each cell is in itself capable of producing a certain value of electric pressure. Hence each battery is capable of developing a certain number of volts.

It is necessary at this time to interpret that condition of maintaining the potential difference between the positive and the negative poles of each cell and the flow of electric current when that cell is connected to a conductor as the capacity of that cell to supply electricity, since the chemical action taking place in the cell is converted into electrical energy represented in the effects produced in the conductor or device connected to the cell. It is possible to so connect cells that the total voltage developed by the complete battery is greater than that developed by one cell or that the total voltage developed by the battery is no greater than that developed by one cell but the quantity of electricity available in the system is greater than that available from one cell.

Batteries or individual cells are shown as short and long lines bearing + and — designations, the former indicating the positive pole and the latter the negative shown by a number of short and long lines (vertical) with the polarity designations at the extreme ends, as in Figs. 63 and 64 These symbols are employed irrespective of the type of battery involved.

Series Batteries

When a voltage in excess of that of one cell is desired from a number of cells, they are connected in series (see Fig. 65), that is, the positive of one is connected to the negative of the other, until all the cells are connected and one free negative and one free positive remain. If the voltage developed by each cell is 1.5 volts, the total voltage of the series combination is the sum of the voltages of each cell, *viz.*—

$$\text{Voltage} = \text{voltage of each cell} \times \text{number of cells.}$$

Parallel Batteries

When the amount of electricity required is greater than that available from one cell and the voltage required is not greater than that developed by one cell, the parallel connection is employed. When a parallel connection is employed all terminals of like polarity are connected together as in Fig. 66. Since the potential of all cells is the same, current will not flow through the cells unless a conductor is connected across the two end leads. Because of the effects of potential difference it is impossible to connect cells of unlike voltage in parallel. An electric current will circulate between the cells needlessly wasting energy. Sometimes it is necessary to secure an arrangement wherein the voltage required is in excess of that developed by one cell and the amount of electricity required is also greater than that available in one cell. In an event of this kind, the cells are connected in parallel-series or series-parallel as shown in Fig. 67.

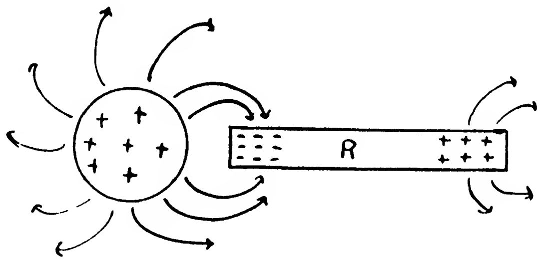


Fig. 68

Induction

The production of voltage by means of induction finds its basis in the fact that a difference of potential can be created when a conducting body is brought near a charged body, the difference in potential being found between that part of the conducting body nearest the charged body and the part fur-

thest away from the charged body as shown in Fig. 68. A difference of potential exists between the two ends of the rod R. If the rod is permitted to stay at rest charges from one end will travel to the other until the charges at the two ends are equal, at which time, no potential difference will exist.

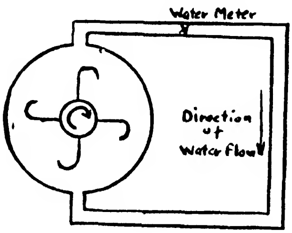


Fig. 69

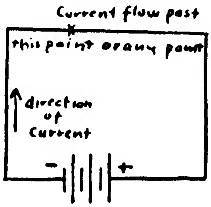


Fig. 70

However, during the time that the charges are in motion and arriving at the state of balance a continual state of activity on the part of the charge will exist. This condition can also be secured by keeping the rod at rest and varying the state of charge of the circle. If we consider the circle as a circuit carrying current, the conductor will then be a charged body and if we vary the voltage causing the current flow through the conductor, we can vary the induced charge and thus cause continued activity in the rod. This phenomenon provides a basis for the production of voltages with devices other than batteries or heat at junctions.

CURRENT

WE KNOW that a pump in action will drive water through a piping system and we know that electric pressure, electromotive force or voltage will cause the flow of electric current through a conducting circuit. Now it is necessary to decide upon the quantity of electricity in a circuit, or the quantity of electric current. This is determined by considering the rate of flow of the electrons past a certain point in the circuit.

We know that if we have a pumping system such as that shown in Fig. 69, where a centrifugal pump is driving water through a pipe, that if the rate of flow at one moment is 8 gallons per minute past the point X (a water meter), that the quantity of water in the system at that time is greater than if the rate of water flow were only 5 gallons per minute past that point. The same is true in the electric circuit. If the rate of flow of electrons past a certain point in the circuit per second is increased, the quantity of electricity in that circuit is increased. Hence a coulomb of electricity is the quantity of electricity in the circuit when 64,000,000,000,000,000,000 electrons move past a certain point in the circuit in one second. Such a quantity of electrons cannot be used in practice, hence a rate of current flow is used, representing number of electrons as units. This rate of flow is the ampere, and it really represents quantity of electricity. It is said that a coulomb of electricity is present in a circuit when the rate of current flow is one ampere per second. As in the water analogue, when the rate of flow is increased or decreased, the quantity of electricity is increased or decreased respectively.

As in the case of voltage, the rate of current flow need not be unity. It may be less or more, hence certain fractions are again mentioned as a prefix denoting the decimal part of the ampere. As examples, when the current is less than 1 ampere

it is customary to mention it as a number of milliamperes, the prefix

$$\text{milli} = \text{one thousandth} = .001 \text{ ampere} = \frac{1}{1{,}000} \text{ ampere}$$

If we wish to state that .087 ampere is the current flow we say 87 milliamperes. If we wish to say that .87 ampere flows in a system, we say that 870 milliamperes is the current in the circuit. The term milliampere appears quite frequently in connection with vacuum tube circuits.

Another prefix denoting a decimal part of the ampere is

$$\text{micro} = \text{one millionth} = .000001 \text{ ampere} = \frac{1}{1{,}000{,}000}$$

ampere

When we are discussing amperes in numerical values greater than unity, the number is used in connection with the term, *viz.* 5 amperes.

Ampere Hour

It is now necessary to refer back to the comment on batteries relative to the quantity of electricity available from any one cell or battery. Batteries are rated in ampere-hours discharge, representing the quantity of electricity available from the battery for a certain period of time. The ampere hour quotation is usually numerical as 10, 50, 80 or 100 signifying that the battery will provide 10, 50, 80 or 100 amperes for an hour or 1 ampere for 10, 50, 80 or 100 hours respectively. One ampere per hour represents 3,600 coulombs, hence a 100 ampere hour battery will provide 360,000 coulombs of electricity during the 100 hours. When batteries are connected in parallel the current flow divides among the number in parallel and each battery contributes to the total current. Thus if four 100 ampere hour batteries are connected in parallel and 4 amperes flow per hour the total quantity of electricity in the circuit for that

hour is

$$\text{Coulombs} = 3{,}600 \times 4 = 14{,}400$$

but each battery contributes and the current flow through each is 4 ÷ 4 or 1 ampere per hour or 3,600 coulombs per hour. Thus the operating life of each battery is increased, since each has a rated operating life prior to recharging, of 100 hours. If the 4 amperes were to be secured from one battery, its operating life prior to recharge would be only 100 ÷ 4 = 25 hours.

Effects of Electric Current

The flow of electric current in a circuit is manifest in several ways. The exact effect depends upon the elements involved. In batteries of the dry type, it is the consumption of the zinc. In electric circuits, it may be heat. If sufficient, the wire will glow, as in the case of the electric light or the vacuum tube filament. If wire is subjected to excessive current it will heat and smoke. If it is covered with an insulating medium such as rubber or cotton, the insulation will burn, thus giving evidence of the heat generated in the wire by the flow of current. If heat is allowed to increase by increasing the current flow through the conductor, the wire will eventually melt. It might be of interest at this time to mention in view of what will follow later in the text, that the heat produced in a wire by a steady current will increase as the square of the current. In other words, if 2 amperes of current produces a certain amount of heat in a wire, and the current flow is increased twofold, the heat produced is increased fourfold. If the current is increased to three times its original value, the heat produced is increased to nine times its original value.

When current is caused to flow through a wire, a peculiar effect is created. This effect is somewhat similar to the field which surrounds a body carrying a certain charge. At every point along a wire, no matter how fine the division, it will be possible to find a point of positive and negative polarity. As such a wire is a charged body and has a field of its own. When

a wire carries a current a field is created around the wire which tends to polarize the wire by creating positive and negative poles, and displays an influence upon a magnetic compass. This field surrounding a wire carrying a current is known as a magnetic field. It is composed of imaginary lines of force, designated as flux. Comprehension of this fact is of importance if one desires to understand the action of many devices employed in electrical circuits.

The illustration in Fig. 71 shows a section of wire carrying a current and the resultant lines of force surrounding the conductor. These flux lines assume the shape of concentric circles around the conductor. The arrows indicate the direction of the flux lines. The S and N designations within the small circle indicate a compass. When a compass is placed near a wire carrying a steady current, the N hunting pole will point in the direction of the flux line progress or the direction of the flux force. A simple method of determining the direction of the flux is to grasp the wire in such manner that the thumb points in the direction of the current flow, in which case the fingers will indicate the direction of the flux lines.

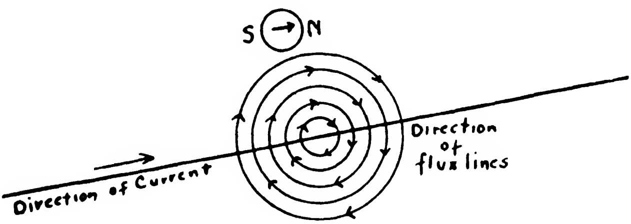


Fig. 71

The presence of these flux lines surrounding a conductor make possible the transfer of energy from one circuit to another without a direct metallic link between the two. It also provides for the production of voltages by means of revolving machinery which make use of such flux. The presence of flux lines around wires carrying current is the basis for the successful utility of alternating current (A.C.) as a source of power.

ELECTROMAGNETIC INDUCTION

The subject of a magnetic field surrounding a wire does not cease with the field around a single wire. If we place two wires, carrying current in the same direction, adjacent to each other, the resultant field surrounding the two wires will be the combination of the individual fields. In other words the total field will be stronger than the field surrounding a single wire. If we take a long length of wire and cause current to flow through it, we find a field around the entire length of wire but at any one point along that length, the intensity of the field is that due to the current in that portion. If however, we take this long wire and wind it into a spiral, the field surrounding each turn will combine with that surrounding the other and we have a very strong field within and around the entire winding. Such a winding is known as a solenoid.

In addition to the fact that the magnetic flux is greatly increased, we find that the winding acts as if it had a North and a South pole, the S pole being where the current enters the wire, and the N pole being where the current leaves the wire. If a substance possessed of magnetic properties like soft iron is brought close to either end of such a winding it will be attracted towards the winding and pulled into the hollow center of the winding. This phenomenon is employed in many control devices. When a bar of iron is placed into the solenoid it becomes polarized, developing a N and a S pole. This magnetism is induced in the iron. When the iron is withdrawn, it looses its magnetic properties. Hence such material can be employed as a temporary magnet, acting only while under the influence of an electric current.

If a piece of steel is placed within the hollow center of the coil carrying a steady current, it too becomes polarized in like fashion, but in contrast to the iron it retains its magnetism

and becomes a permanent magnet. Magnetism in both the iron and the steel is once more a state of molecular activity. The molecules of the iron or the steel while under the influence of the electric field alter their position, each molecule of iron and steel becoming a small magnet. In the case of iron the normal position of the molecules obtains when the current ceases. In the case of the steel the molecules remain as fixed by the electric current even after the current ceases.

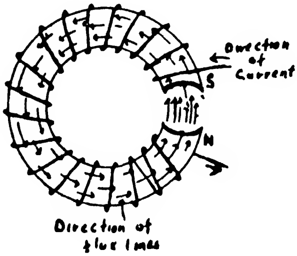


Fig. 72

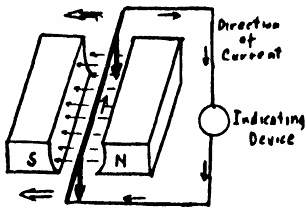


Fig. 73

Iron Core Windings

The use of a magnetic core for a coil produces certain definite advantages. Without the core, the flux produced by the current flow through the wire, must flow through the surrounding medium which is the air. If we supply a medium which is a better conductor of the flux lines, more of the lines of flux generated by the current flow in the wire are arranged to combine with other lines and may be employed to good advantage. This will become evident later in the text.

If we arrange a semi-circular iron core and wind wire upon this core as in Fig. 72, we find that a magnetic field is created across the gap, which field exists while the current is flowing through the wire. The ends of the core assuming polarity as shown arrange to magnetize a horseshoe shaped piece of steel, the current may cease in the wire, yet a magnetic field will be present across the gap between the North and the South pole of the magnet. Thus we have flux lines between the poles of a magnet.

Induced Voltages

If current flow through a conductor produces flux in a magnet, it stands to reason that there must be some relation between the flux of a magnet and a conductor. Herein lies the principle of the production of voltages with revolving machinery.

Dynamos

If a conductor is arranged within a magnetic field as in Fig. 73, and moved in the direction of the heavy, single arrows, at an angle to the lines of force present between the N and S poles of the magnet (lines of force being indicated by the light arrows) a voltage will be induced in the conductor while it is in motion. However, if the conductor is moved parallel to the lines of flux, as shown by the double line arrows, no effect will be visible upon the indicating device. This method of producing an electric potential which will cause the flow of current around a conductor connected to the wire being moved in the magnetic field is electromagnetic induction, by moving a wire across magnetic lines of flux, or by cutting lines of flux.

As is evident by the arrows indicating direction of current flow and movement of the wire within the field, the direction of the induced voltage and the current flow is related to the direction of the flux and the direction of the magnetic field existing between the two poles of the magnet. If the con-

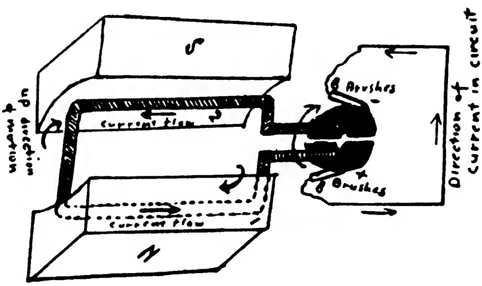
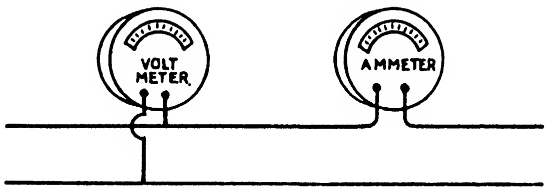


Fig. 74

ductor were moved in the direction opposite to the heavy arrows "up" instead of "down," but cutting the flux lines in

the same manner, the direction of the induced voltage and current flow would be opposite to that shown in the illustration.

If a loop of wire arranged to revolve in the fashion of the conductor shown in Fig. 73, is arranged as in Fig. 74, it is possible to induce voltage in such manner in the two conductors that current will flow in one direction in the external circuit connected to the conductors revolving within the magnetic field. The two parts marked B are the brushes which make contact with the two semi-circular rings, so arranged that when the coil is revolving (being rotated by separate mechanism) along



VOLTMETER CONNECTED IN MULTIPLE
AMMETER CONNECTED IN SERIES

the axis shown, the coil side passing the N pole of the permanent magnet is always connected to the same brush. In other words when coil side 2 is passing the N pole in the down direction, it is connected to the brush B marked with the + sign. An arrangement of this kind is called commutation and is employed in D.C. generators, a simple example of which is shown in Fig. 74. The combination of the brushes and the ends of the loops arrange for reversal of the connections to the loops, so that as far as the external circuit connected to the generator is concerned, the current flow through the circuit is always the same.

In regular D.C. generators there are many such loops and many such segments so arranged that the proper segment makes contact with the brush at the proper time, keeping the current flow always in the correct direction in the external circuit. This is the operative principle of the D.C. generator.

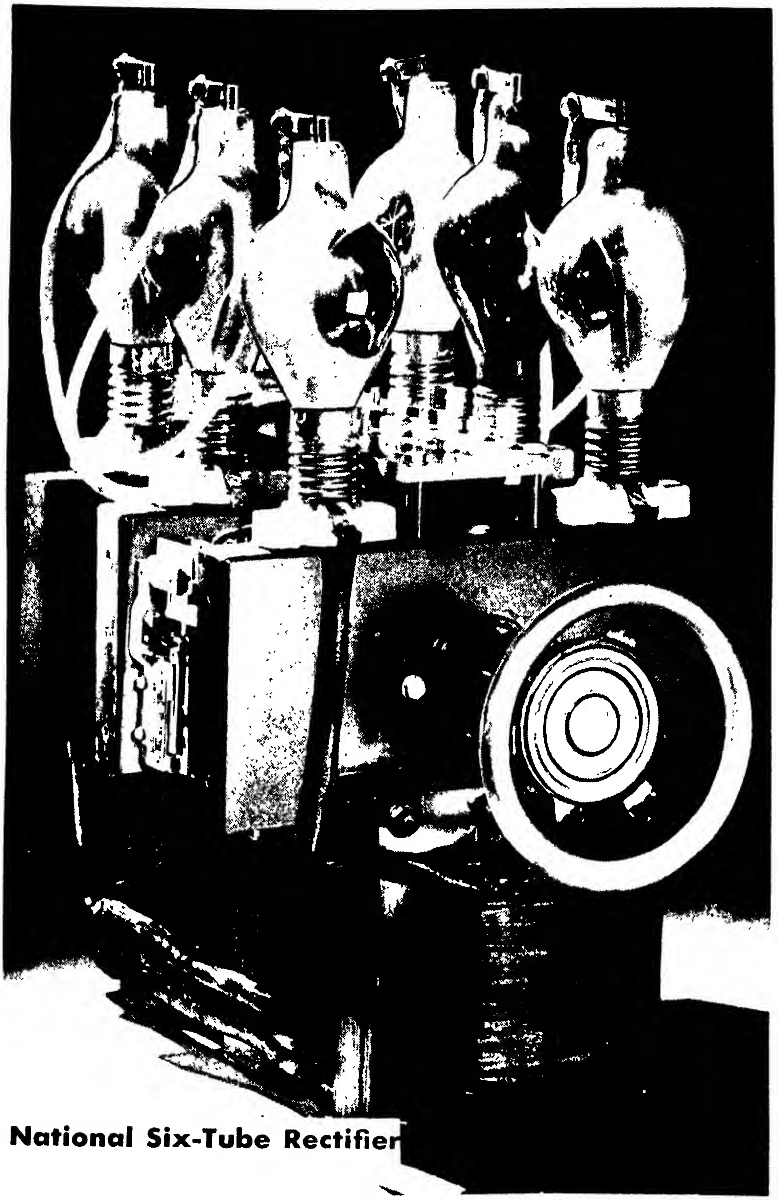
DIRECT CURRENT CIRCUITS

THE polarity of the voltage applied to a circuit governs the direction of the electronic drift and the flow of current. If the direction of the electronic drift is always the same and the direction of the current flow is always the same, the electronic drift or the electric current is naturally continuous in one direction and the circuit is known as a continuous current circuit or as a D.C. circuit. If the voltage applied governs the direction of current flow, and if the current is D.C., the voltage must also be D.C. although the letters D.C. denote direct current or continuous current the symbols are synonomous for voltage which will cause direct current.

We have determined that D.C. voltages may be produced in three ways. Let us now concern ourselves with the D.C. electric circuit. We stated that an electric circuit has an excellent analogue in the water pumping system. See Figs. 69 and 70. The rate of water flow is, of course, governed by the pressure of the pump. Another factor is the frictional resistance offered to the flow of water by the piping system. If the frictional resistance is great the rate of water flow will be reduced and the quantity of water in the system will be reduced. The same thing holds true in electrical circuits. The voltage causes the flow of current, but the rate of flow is governed by not only the voltage applied but also by the resistance of the electrical circuit, that is, the resistance of the conducting path.

RESISTANCE

Resistance is that force which retards the flow of current and its usual designation is a zigzag line. The property of resistance is possessed by all substances and the variation of re-



National Six-Tube Rectifier

sistance among substances of different character is again a matter of electrons. If electronic activity, *i.e.*, the movement of an electron from one atom to another, is easily accomplished that substance is a good conductor of electricity. If however, such activity is impaired because of the constituency of the atom, the substance is a poor conductor. Certain wires of special material possess this property of offering great resistance to the flow of electric current and are therefore known as resistance wires. Carbon and graphite in certain forms can be arranged to function as a high resistance.

The unit of electrical resistance is the ohm. Like voltage it may be expressed as a fraction or as a multiple of the unit. In the case of resistance, application of a prefix to denote a value less than an ohm is seldom used in practice. As a matter of fact the regular numerical value is used for all values of resistance up to and including about 5,000 ohms. When the resistance value is in excess of one million ohms, the prefix "meg" is applied to denote a million, as for example

2,300,000 ohms = 2.3 megohms

In certain cases, resistance greater than unity is expressed as a fraction of a million ohms, *viz.*

2,000 ohms =	.002	megohm
30,000 ohms =	.03	megohm
400,000 ohms =	.4	megohm
1,000,000 ohms =	1	megohm

The resistance of metallic conductors depends upon 1. Constituency, 2. Cubic dimensions, 3. Temperature. Generally speaking the resistance of a given conductor is proportional to the length and inversely proportional to the cross section. In other words if the length of a given conductor is doubled, the resistance increases twofold and if the cross section is doubled, the resistance decreases to one-half its original value.

Temperature has an effect upon resistance offered by different substances. Increase in temperature increases the resistance of pure metals. The extent of increase depends upon the exact metal. Alloys of metals increase in resistance to a

smaller degree than pure metals. Hence such metals are employed where resistances are operated at high temperatures and where it is necessary that the value of resistance remain constant. The percentage variation in resistance with each increase in temperature above a standard value is known as the temperature coefficient. If the variation in resistance with increased temperature is an increase, the temperature coefficient is positive. If the variation in resistance with increased temperature is an increase, the temperature coefficient is positive. Carbon, glass, porcelain and quartz have negative temperature coefficients.

The above statements relative to the variation in resistance with heat are the reasons for the use of wire wound resistors wherever they may be secured in the proper values of resistance. Sources of potential which are so arranged that several values may be secured by proper arrangement, make use of wire wound resistances because the ohmic value remains constant at the predetermined figure.

Ohms Law

Associating the simple D.C. circuit with the water analogy, it stands to reason that a certain relation must exist between a difference of potential which causes a voltage, the current in the system, and the resistance which limits the rate of current flow. When discussing voltage, current and resistance it is customary to abbreviate these terms. The capital letter E being employed to denote voltage, the capital letter I being employed to denote current and the capital letter R being used to signify resistance. A definite relation between the voltage E across any two points in a circuit and the current I was found to exist by Simon Ohm, a physicist. He expressed this relation as follows, assuming that the voltage remained constant and that the physical state of the wire in the circuit remained constant.

$$\text{Resistance (R)} = \frac{\text{Voltage (E)}}{\text{Current (I)}} \qquad (1)$$

$$\text{Current (I)} = \frac{\text{Voltage (E)}}{\text{Resistance (R)}} \qquad (2)$$

$$\text{Voltage (E)} = \text{Current (I)} \times \text{Resistance (R)} \qquad (3)$$

It is evident from the above that the resistance in a circuit with constant voltage varies inversely with the current. In turn the current in a circuit with constant voltage varies inversely with the resistance and with a constant resistance varies in proportion to the voltage. The voltage is proportional to the current with constant resistance and to the resistance with constant current. Wherever the current and resistance are constant, the voltage E or I R is constant.

This method of determining current, voltage and resistance is applicable to every form of D.C. circuit, wherever two of the values are known quantities.

In order to have current in a D.C. circuit we must have a continuous path for the current. If some part of the system is open, current will not flow. Essentially every circuit consists of two parts, that within the device which produces the electric force and the part external of the source of voltage. Special mention is made of this fact because in many instances current does not flow in a circuit because an open is located within the supposed source of voltage.

The electric circuit may be divided into three classifications, 1. series, 2. parallel, and 3. series-parallel. The distinction between the three is the action of the current in the circuit with respect to the applied potential.

Series Circuit

If the current in any circuit is the result of the applied voltage and the resistance, the work done to cause the flow of charges through a resistance, should be equal to the rate of flow times the resistance. If we have a number of resistances in a circuit, connected in series fashion, the current in the circuit is the voltage divided by the combined resistance.

Parallel Circuits

Another circuit is the parallel arrangement and the definition of the system entails "a circuit which has two or more elements connected between the same two points in the circuit." Such a circuit is shown in Fig. 75. With two resistances in parallel the current is no longer the same in all parts of the circuit. The main current I divides between the two resistances R and RI representing two separate branches. In the series circuit the current was the same in all parts of the circuit. In the parallel circuit the current is not the same but the voltage is the same. In the parallel circuit the current divides according to the resistance of each branch and the sum of the branch currents I1 and I2 is the total current I.

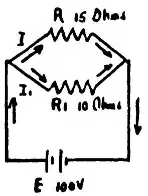


Fig. 75

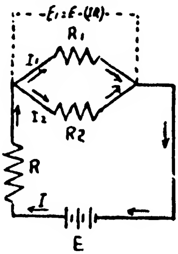


Fig. 76

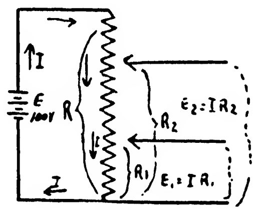
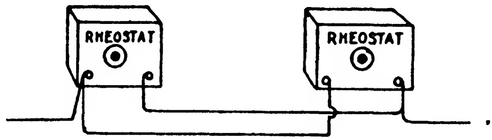


Fig. 77

The series-parallel arrangement is a combination of series and parallel parts as in Fig. 76. The solution resolves itself into the determination of the joint resistance of the parallel combination of R1 and R2, at which time the resultant resistance Rx will be in series with R which will allow for the determination of the total current I. The voltage impressed across R1 and R2 is E1 = E — (IR). The current through R1 is then E1 divided by R1 and through R2 is then E1 divided by R1 and through R2, E1 divided by R2.

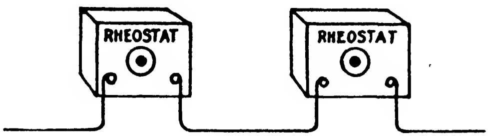
Comprehension of series and parallel circuits of this type is very important because the arrangements are used in very many other examples, such as circuits whereby certain disturbing noises are eliminated, excessive loudspeaker intensity on

certain notes is reduced, electrical meters are arranged for increased operating scales, etc. Complete assimilation of what will follow in connection with voltage drop in series circuits explains the action of the fader and the utility of various forms



RHEOSTATS IN MULTIPLE

of voltage divider devices, such as volume control units in amplifiers and voltage distributing resistance in certain A.C. operated devices which furnish D.C. operating potentials.



RHEOSTATS IN SERIES

A.C. VOLTAGES

The use of alternating current affords many advantages not available in D.C. circuits. We have determined that a circuit wherein the electronic drift is continuously in one direction and the electric current is continuously in one direction, is a direct current circuit. The alternating current circuit differs in the respect, that neither the electronic drift or the electric current flows always in one direction. Instead they change their direction of flow periodically with a definite relation with respect to time. The best method of illustration is to show the method of generating a wave of alternating current with revolving machinery.

The voltage secured from a D.C. source is constant and remains constant with respect to time until the battery is worn out, or the speed of the generator is reduced, in the event that the source of D.C. is a dynamo or generator. With A.C. equipment, the voltage does not remain constant, but instead is continually varying and the current in the system is continually varying. This property of the A.C. circuit enables the achievement of many effects not available with D.C. Primarily it is the transfer of energy from one circuit to the other, the stepping up of voltages and the reduction of voltages from a higher to a lower level.

The general representation of a direct current is a straight line a certain distance above a zero line, indicating constant potential or current, as in Fig. 78. The general representation of alternating current is different as evident in Fig. 79. Here we find a symmetric wavy line extending both sides of a zero line and at certain periods passing through the zero line. Since the ordinate in both cases represents current, it is evident that alternating current is steady at any one value but for an instant. We also note that it passes through the successive

value from zero to maximum with a definite regularity. Such a wave is known as a sine wave of A.C. The reason for its shape becomes evident when one considers the generation of the current which means the generation of a force which will produce such current in a circuit connected to the generator.

One of the laws of electricity states "that if a coil of wire is revolved in a uniform parallel field, a sine wave of Alternating Voltage will be produced." We shall make all of our references to current and the voltage should be understood. Commutation is not employed in A.C. Instead two contacts remain connected to the two conductors and these contacts are not reversed with each revolution of the coil. Let us follow through the movements of a coil being revolved in a parallel field. Fig. 80 shows a different view of the alternator (A.C. generator). We are now gazing directly upon the revolving loop having removed the two slip rings because they obstructed our view. The two coil sides revolve in the space between the N and the S pole in the direction shown by the dotted lines. The two arrows external of the pole pieces show the direction of the magentic field between the pole pieces. We show them external of the gap between the pole pieces because they interfere with the comprehension of what is within the gap. The heavy dot marked 1 represents one coil side and the dot marked 2 represents the other coil side. If the two arrows indicate the direction of the magnetic field, the two coil sides at the moment are parallel to the field hence no voltage is induced in the windings. We have drawn a reference line representing zero voltage in the coil, hence zero current in the external circuit. We are going to plot on this line the voltage induced in the coil with respect to its angle of rotation time. We are going to revolve the loop in a counter-clockwise direction. When coil side 1 is at point C it will have completed an angle of rotation of 90 degrees with respect to the reference line. When it will have moved to E, the angle of rotation will have been 180 degrees. At G it will be 270 degrees and when back at its normal position A, the coil will have revolved 360 degrees. We shall plot upon the reference line these four angles of rotation spaced uniformly.

The arc through which the coil sides are moving has a radius Em. The instantaneous voltage induced in a single turn loop revolving at constant speed in a parallel field is directly proportional to the sine of the angle it is making with the initial position at that instant. If the coil moves up to point B it completes the angle BOA. A vertical projection from the point B will represent Em sine *O*. The angle of rotation was 45 degrees so we carry a line from the point B to the 45 degree point on the reference line. In other words we project the point B upon the reference line. At C, *O* equals 90 degrees. During this 90 degree turn, the coil side 1 is in the position shown in Fig. 63 with the current flowing in the direction as shown. At this point the coil is cutting the lines at 90 degrees. Now the angle increases as the coil passes to D, having passed through 135 degrees. As the angle changes from 90 degrees to 135 degrees, the vertical projection decreases at the same rate that it increased. Coil side number 1 is now moving further away from the N pole and approaching a direction of motion parallel to the field. The voltage induced and the current flow still remains in the same direction but they have decreased in magnitude. When *O* is 180 degrees, the coil side is parallel to the direction of the field and no voltage is being induced. Thus far the vertical projections have been above the zero line and are called positive with respect to the zero line. Coil side 2 is now where coil side 1 was before. Now coil side 2 is passing the N pole as did side 1, and side 1 is now passing the S pole like did side 2 before. Since the direction of the induced e.m.f. and the current flow is dependent upon the direction of motion of the conductor with respect to the direction of the field, the current now leaves from the slip ring connected to coils side 2 and the continued projection of the rotation of coil side 1 is below the zero line, showing that the direction of the induced voltage and the current flow has been reversed. The process above the zero line is now repeated below the zero line until the cycle of rotation is completed, and the cycle of voltage or current appears like that shown. Thus we see that the current is actually reversed in the circuit because the direction of motion of the coils through the field is changed. Supplementing this

is the fact that the variation in potential and current is gradual and not abrupt. Thus the electronic drift in such a circuit starts at zero, reaches maximum in one direction, decreases to zero in the same direction, reverses itself and repeats the process in the opposite direction.

We find a definite variation of voltage and current with respect to time, as expressed in angle of rotation. A complete cycle is a rotary movement of 360 degrees. The frequency of

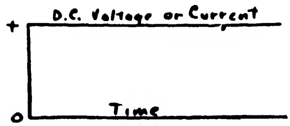


Fig. 78

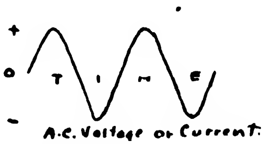


Fig. 79

the cycle is the speed of completion of a whole cycle. If the cycle of rotation is completed once in 1 second, the frequency is 1 cycle per second. If it is completed in one-sixtieth of a second, the frequency is 60 cycles per second, etc.

If we study this cycle of current we find that a complete cycle consists of two alternations of 180 degrees each. Further that a complete cycle entails three zero points. The zero points are always taken as reference. We also find that the height of the wave represents the amplitude, or the point of maximum potential. Thus each alternation has a single point of maximum potential, and there are two points of maximum potential in each complete cycle. The illustration mentioned herein is with a two pole machine. In a four pole machine the angle of rotation would of necessity be less for a complete cycle, and the required speed to produce the same frequency would be half of that required of the two pole machine.

Now we become aware of the fact that the current in such a circuit is constant for but an instant. How is it possible to decide upon the amount of work done, that is, the effective value, considering two instantaneous maximum and three instantaneous values of zero current for each cycle. The method of arriving at a definite numerical basis for a certain value of alternating current, is to employ its heat generating power in

CARRYING CAPACITY OF COPPER WIRE

B. & S. Gauge	*Circular Mils*	*Table A Rubber Insulation Ampere*	*Table B Other Insulations Ampere*
18	1,624	3	5
16	2,583	6	8
14	4,107	15	16
12	6,530	17	23
10	10,380	24	32
8	16,510	35	46
6	26,250	50	65
5	33,100	54	77
4	41,740	65	92
3	52,630	76	110
2	66,370	90	131
1	83,690	107	156
0	105,500	127	185
00	133,100	150	200
000	167,800	177	262
0000	211,600	210	312
	200,000	200	300
	300,000	270	400
	400,000	330	500
	500,000	390	590
	600,000	450	680
	700,000	500	760
	800,000	550	840
	900,000	600	920
	1,000,000	650	1,000
	1,100,000	690	1,070
	1,200,000	730	1,150
	1,300,000	770	1,220
	1,400,000	810	1,290
	1,500,000	850	1,360
	1,600,000	890	1,430
	1,700,000	930	1,490
	1,800,000	970	1,550
	1,900,000	1,010	1,610
	2,000,000	1,050	1 670

The lower limit is specified for rubber-covered wires to prevent gradual deterioration of the high insulations by the heat of the wires, but not from fear of igniting the insulation. The question of drop is not taken into consideration in the above tables.

a known resistance. The heat produced in a resistance is independent of the direction of current flow, hence it is possible to compare A.C. with D.C. This is done, and alternating current is said to have an "effective" value of 1 ampere if it produces the same heating effect in a known resistance as 1 ampere of direct current. By comparison with D.C. and by applying the known relation of heat being proportional to the square of the current, it has been determined that the effective value of alternating current is

$$.707 \times \text{the maximum value}$$

Also that the maximum instantaneous value of current is equal to

$$1.414 \times \text{the effective value.}$$

Since the effective value represents the square root of the mean of the squared instantaneous values, the effective value is frequently mentioned as the "root mean square" or the

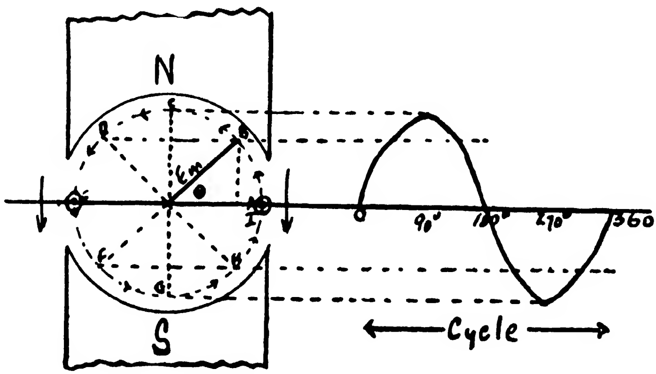


Fig. 80

r.m.s. value of alternating current. This is the value indicated upon A.C. measuring instruments or meters, unless the instrument is of such design that it measures the maximum or peak value.

TRANSFORMERS

THE successful application of A.C. is based to a very large extent upon the phenomenon known as induction, whereby it is possible to transfer energy from one source to another without a direct metallic link between the two.

MUTUAL INDUCTANCE

Comment made thus far in connection with inductance referred to the induction of a voltage in a coil by the flux produced by that same coil, in other words self-induction. Since the voltage is due to linkage between flux lines and a circuit it is possible to produce flux by passing current through a coil and to locate a second coil within the magnetic field and thus induce a voltage in the second circuit. Of course in the case of self-induction, the production of an e.m.f. across a coil depends upon a variation of the number of linkages. This means that a definite condition must obtain in such an arrangement in order that voltage be induced in the second coil. First, the field must vary. If the field is stationary, the coil must vary with respect to the field so as to cause a change in linkings. If the two coils, 1 and 2, are stationary, the field must vary and this is secured when A.C. supply is used.

An arrangement representative of what has been said is shown in Fig. 81. Current in coil 1 produces a flux which links with the turns in coil 2, induces an e.m.f. across the terminals of each turn, hence across the entire coil. If the circuit is completed as shown, current will circulate in circuit 2. Here are two circuits without direct metallic contact yet energy is transferred from one to the other by means of flux. Thus the flux is a linking medium. Recognizing the action with respect to the requirement of a change in linkings in order to induce a voltage, one

can readily comprehend that such effects cannot be secured if the current flowing in coil 1 is of steady character such as that which would obtain if the voltage E were D.C.

If the voltage applied to coil 1 is D.C., there will be a momentary current voltage in coil 2 when circuit 1 is closed and

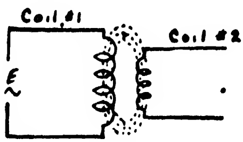


Fig. 81

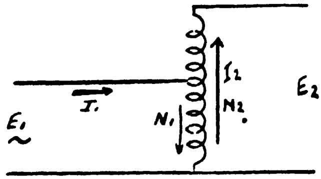


Fig. 82

again when it is opened. If the voltage is held constant and circuit 1 closed, it would be necessary in order to induce a voltage in coil 2 to continually vary the relative position of coils 1 and 2. An arrangement of two coils so arranged that flux links two circuits or turns in two circuits constitutes the transformer. This device finds very frequent application in a sound motion picture system. It serves as a means of increasing the magnitude of the electrical equivalent of a sound wave. It serves as a means of supplying the correct operating potentials for the various tubes in the amplifying system. It serves as a means of transferring energy from an amplifier to the various reproducers.

Generally speaking the function of a transformer is to transfer electrical energy from one circuit to another. Also to transfer electrical energy at various voltages. Recognizing that the basis for its action is flux linkage, it is possible to arrange such transformer action without having two separate windings. If one inductance is used, which is so apportioned that the inducing current flows through a portion of the winding and the flux so produced cuts the remainder of the turns of the complete coil, we have an "auto-transformer," as shown in Fig. 82. The inducing current flows through the turns designated as N1. The flux produced cuts all the turns designated as N2, developing an e.m.f. E2 across N2 and causing current I2. This de-

vice will find application in audio amplifiers and also in devices employed to charge storage batteries or to supplying one form of operating potential to the vacuum tubes in the system. Thus the flux links two coils and the flux common to both coils is therefore mutual and known as the mutual inductance of the two coils.

Audio transformers employ cores consisting of a magnetic substance. This core is so arranged that it provides a complete magnetic path between the two coils thus assuring better and greater linkage between the two coils. The basis transformer is one which employs two windings or coils, similar to the schematic shown in Fig. 81 but arranged as shown in Fig. 83. Each one of these windings bears a name. The winding which receives the electrical energy is known as the input or primary winding. The winding which supplies the energy from the transformer is known as the output or secondary winding. These two coils are designated as P and S respectively. The arrangement of the coils depends upon the structure of the transformer. In some units the windings are wound upon opposite legs of the core as shown. In others the windings are atop each other and wound upon one leg. In still a third ar-

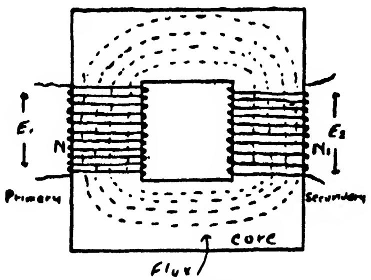


Fig. 83

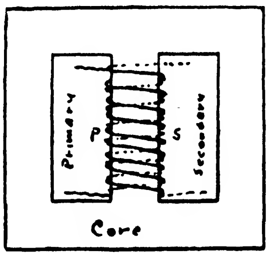


Fig. 84

rangement, the windings are atop each other and wound about a center leg of the core as shown in Fig. 84

The number of windings used in a transformer depends upon the design. Usually the primary winding is singular, but the secondary may be more than one. If three or four output

windings are desired they are individual and located in various ways.

If the voltage output of the secondary is greater than the voltage input to the primary, that transformer is said to be a "step-up" transformer. If the output voltage is less than the input voltage, the transformer is spoken of as a "step-down" transformer. In many instances the transformer used consists of several output windings which provide different values of output voltage, higher or lower than the input. No special name is given to such a unit, since it is a combination of both designations stated.

We know that if an alternating voltage E is applied across a winding of N turns wound upon a core, a current I will flow

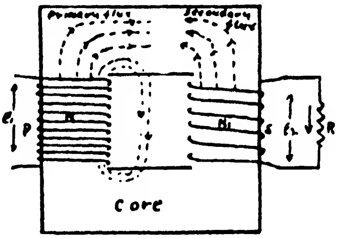


Fig. 85

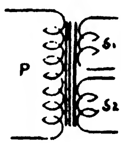


Fig. 86

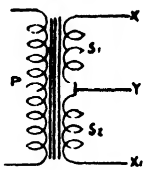


Fig. 87

and a flux is produced. The magnitude of this current will depend upon the impedance of the winding. If the resistance of this coil is classed as being negligible, the current through that winding will be limited by the e.m.f. of self-induction due to the flux produced in the core, and the current will adjust itself so that the magnetizing force which is equal to the current times the number of turns or NI in this case, is just enough to produce the flux required. Referring to Fig. 83 E1 is the applied voltage, "i" is the current and N is the number of turns in the primary. The flux set up in the core cuts the turns N1 of the secondary winding. If we assume that all the flux produced by the primary cuts all of the turns in the secondary winding, a voltage E2 will be induced in the secondary winding. The primary voltage varies with respect to the sec-

ondary voltage like the ratio between the number of turns in each winding and when expressed as a term is

$$\frac{E1}{E2} = \frac{N}{N1}$$

This is best understood by imagining that N = N1. The flux produced is due to the current through N. That amount of flux in turn cuts the same amount of turns, hence the voltage induced is equal to the voltage applied.

The voltage output varies as the ratio between the secondary and the primary turns, for example, if the voltage input is 100 volts and the number of primary turns is 1,000 and the secondary turn consists of 10,000 turns the voltage ratio will be

$$\frac{10{,}000}{1{,}000} = 10$$

and the voltage output with a known input E1 will be

$$\frac{N1}{N} \times E1 = \frac{10{,}000}{1{,}000} \times 100 = 1{,}000 \text{ volts}$$

It is, however, unsafe in practice to assume that all of the flux produced by the primary will cut the secondary turns hence the turn ratio is not the voltage ratio. This is further augmented by an I_R drop in the windings and also the flux condition found when current flows in the secondary winding. Losses in the core material also influence the voltage relation.

The flow of current in the primary caused the generation of flux. The same is true if a load is connected across E2 (Fig. 83). If the voltage E2 causes current in the external circuit as shown in Fig. 85, a flux will be produced by the turns N1. The direction of this flux is opposite to the direction of the flux due to the current in "I" in the primary. This action tends to reduce the flux due to the primary and to reduce the flux cutting the secondary turns. The final result is a reduction in output voltage. Since current flow and no current flow in the

secondary circuit represent "load" and "no load" respectively, "the no load" voltage output of a transformer is always higher than the voltage under load. This item is of interest when transformers are employed to supply the operating potentials for the filaments of vacuum tubes.

With respect to the current relation between secondary and primary windings, the current in the primary during "no load" condition of the secondary is just sufficient to magnetize the core and to create enough flux to produce the correct counter e.m.f. across the primary. When current flows in the secondary, the secondary flux reduces the primary flux and thus reduces the counter e.m.f. across the primary. This action quite naturally allows greater current to flow through the primary winding. Thus the greater the current in the secondary winding, the greater is the current in the primary winding, the latter increasing or decreasing as the former is increased or decreased.

The relation between primary and secondary current is again a ratio of the number of turns and since $N \times I = N1 \times I1$ the ratio of secondary to primary current is.

$$\frac{I1}{I} = \frac{N}{N1}$$

In other words if the number of turns in the secondary is greater than the turns in the primary the voltage output will be greater but the current will be less. The current varies inversely as the number of turns. Thus there is a balance between current and voltage. If the voltage is "stepped-up," the current is "stepped-down" and vice-versa.

This relation seems to indicate that while it is possible to manipulate voltage or current, the power in the system is definitely limited. The action of the transformer is to transfer power from one voltage to another voltage. In the ideal transformer without losses, the output power would be equal to the input. This however is not the case in practice. The average transformer employed to furnish power is about 70 to 90% efficient in small sizes and as high as 97 or 98% efficient in large sizes.

Since there is a difference between the "no load" and "load" (load in this case means full load) value of output voltage, the transformer possesses a characteristic known as the voltage regulation, which indicates how the output voltage varies during the two conditions cited. The per cent regulation is based upon full load and constant input voltage. The voltage regulation in per cent of the average power transformer employed in a sound motion picture system is

$$\frac{{}^{E}\text{full load} - {}^{E}\text{no load}}{{}^{E}\text{no load}} \times 100 \text{ per cent}$$

The degree of operating efficiency possessed by a transformer is to a very large extent governed by the substance used as the core or flux path. If this material is efficient and offers very little resistance to the flow of flux, the operating efficiency of the complete transformer will be higher. That property which offers resistance to the flow of flux in a core is known as reluctance. The unit of reluctance is the "oersted." As in the case of resistance possessed by a conductor, the reluctance of a core is governed by three factors, length, cross section and permeability. Expressed in the form of a formula it is

$$\text{Reluctance} = \frac{\text{length of core in centimeters (physical dimension)}}{\text{permeability} \times \text{cross section in centimeters squared}}$$

Generally speaking reluctance is directly proportional to length and varies inversely as the cross section and permeability.

Primarily the transformer consists of two windings, a primary and a secondary. Current is caused to flow through the primary and a voltage is induced in the secondary winding. Recognizing the significance of this statement and in view of what is to follow, it is necessary that the reader understand that a voltage may be produced across the secondary winding without current flow in the external circuit connected to the secondary winding. Also that under certain conditions, a voltage is available across the secondary winding when a load is connected to the secondary and current flows in the external circuit. The importance of this will be realized when transform-

ers of the types employed in amplifying systems to link tubes, are. used.

Split Windings

It is evident that the important item with respect to the voltage output available from a transformer depends upon the turns employed in the primary and secondary windings. Assuming a certain constant number of turns in the primary coil, it is possible to employ two secondary windings as in Fig. 86. The vertical lines between such windings indicates a transformer employing a magnetic core referred to as an iron core transformer. The voltage available from S1 and S2, depends upon the ratio between S1 and P and between S2 and P. As is obvious S1 and S2 are individual. Each is a source of voltage. If the two windings are connected in series, the two then function as one winding of a greater number of turns, as in Fig. 87. The voltage across the two end leads will be governed by the ratio of the total turns NS1 ÷ NS2 and Np, the turns in the primary. Such an arrangement provides a means of securing a value of voltage in excess of that available from one single winding. If the junction between the two windings is considered as a common terminal, it is the equivalent of a center tap and the two windings are considered as a single winding of NS1 + NS2 turns. The total voltage across X and XI is equal to XY + XY1, or the sum of the voltages of each half of the winding is equal to the total voltage.

Such center tapped windings find frequent application in various radio systems. Since the point Y is the midpoint of the winding, connection to this point provides a point of electrical balance in the circuit. If the voltage XY is applied to one device and the voltage X1Y is applied to another device and the point Y is common to both, each of these devices is being supplied with power across XY and X1Y respectively. If current is caused to flow through the circuit XY it is independent of the current which is caused to flow through X1Y. Such a condition is found in certain systems employed to produce operating potential by converting A.C. power into D.C. power.

RECTIFIERS

The rectifier, briefly, is not a generator of voltages, but rather is a uni-directional valve offering relatively low resistance to a flow of current in one direction as opposed to a high resistance to similar passage in the other. The manifold mechanical forms this electrical principle has assumed in recent years include not only the original purpose of converting alternating to direct current but also a variety of related and extended applications having wide industrial use.

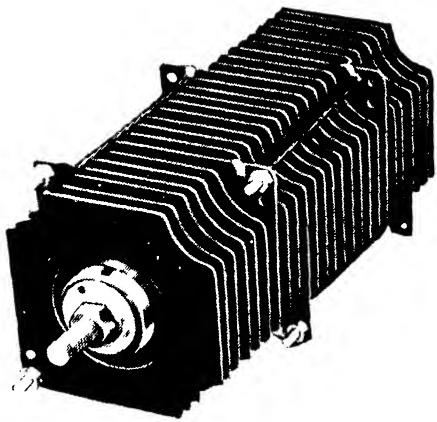
MERCURY-ARC RECTIFIERS

The nature of the cathode spot formed on the mercury pool determines the rectifying action of mercury-arc rectifiers. As the cathode in this device is the only electrode to which current can flow from the ionized space, any inverse currents to the anode are neglected. Subject to variations with temperature and circuit conditions, cathode spots usually require a current of four or five amperes for their maintenance. When this current is no longer sufficient, the spot extinguishes rapidly, a condition causing potential surges in the circuit from energy stored in any inductances that may be in series with the rectifier. To overcome the high-potential gradient in cathode spots, special starting means consist of an electrode dipping in a mercury reservoir connecting with the cathode when the tube is dipped. A conducting path on the tube's exterior and formed with the aid of aqueous colloidal graphite serves the same purpose.

For output voltages less than 100 volts no anode shielding is required. Current ranges cover 10-300 am-

peres and can be increased somewhat for short periods without failure. The arc-drop for rectifiers having unshielded anodes is about 15 volts, a condition that increases the operating temperature and hence affects the potential handled.

TUNGAR



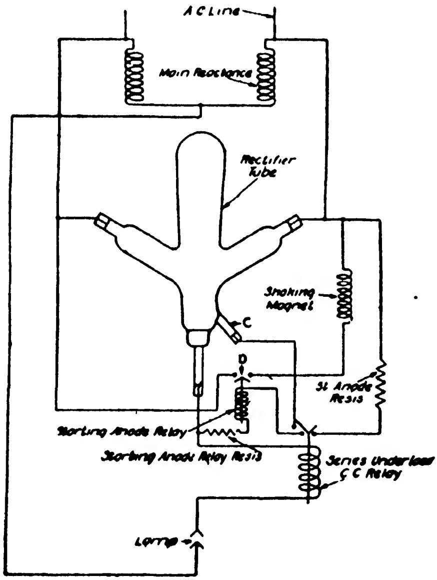
COPPER-OXIDE

HIGH-VACUUM, HOT-CATHODE UNITS

A positive potential applied to a cold electrode will collect, under conditions of an electrical field and corresponding potential drop, the electrons emitted by a heated pole and thereby cause a non-reversal flow of current. By insuring a highly evacuated space for this transfer a rectifying device can be made to withstand

a high inverse voltage. Within the limits governed by space-charge effects and resulting power losses, the cathode can be made larger and the currents carried thereby increased.

Somewhat smaller types of hot-cathode valves, more popularly known as high-vacuum half-wave rectifiers are most efficient in supplying the d-c voltage requirements of cathode-ray tubes. As voltage doublers, two of these types may be operated to deliver approximately twice the voltage obtainable from the half-wave method for the same a-c input voltage.

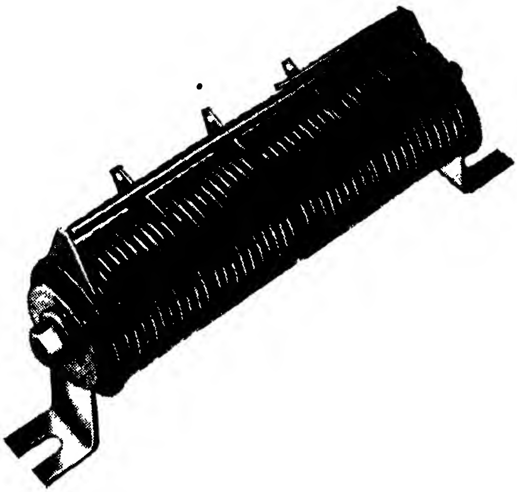


HOT-CATHODE, GAS AND VAPOR FILLED

When the space between a hot tungsten cathode and a cold graphite anode is filled with argon, the positively charged gas ions neutralize the space charged and permit the passage of current without appreciable loss. The required gas pressure varies from about 0.01 mm to 7 cm, any value in excess of these tending to cause a beakdown accompanied by a reversal of the current's

direction.

Liquid or amalgam mercury is used in place of argon gas to avoid space-charge losses. Unlike the gas filled type whose operating pressure can not be controlled due to internal absorption, the pressure of the mercury vapor can be varied by temperature regulation. Within the limits of pressure and size, these rec-



SELENIUM

tifiers have an internal drop of 5-15 volts and a breakdown potential of 400-20,000 volts.

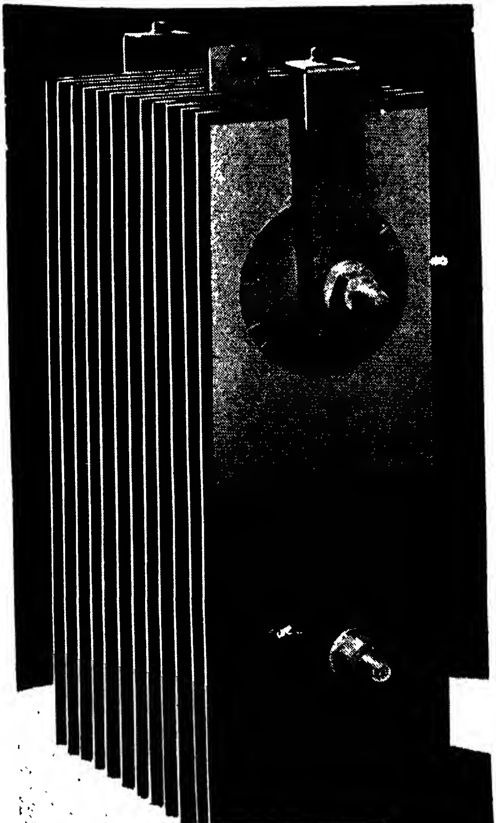
COLD-CATHODE GAS RECTIFIERS

Two electrodes of different area, shape, and substance sealed in helium will discharge with different volt-ampere characteristics in two directions. The difference in electrode dimensions plays the most important part in the operation. With small anodes and larger cathodes the useful rectified current may be twenty times the inverse currents automatically set up in the device before the capacity limit or point of maximum cathode coverage is reached.

The arc-drop is about 100 volts, thus causing efficiencies of less than 50%.

GRID-CONTROLLED VALVES

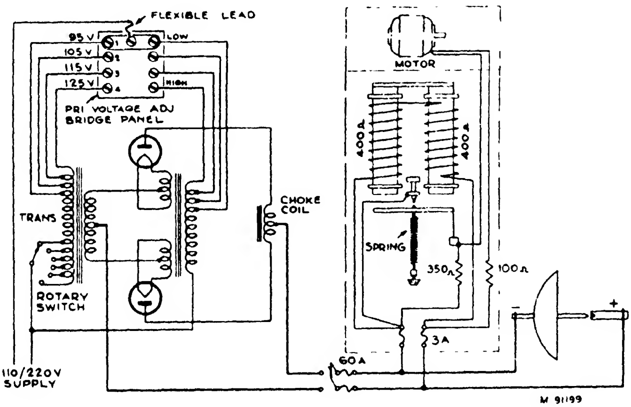
In the thyratron and grid-glow rectifiers of the gaseous type a grid determines whether an arc is formed while the plate is positive with respect to the filament.



National Copper Oxide

If a voltage is applied between the anode and cathode with a sufficient negative grid-bias present, the tube operates like an ordinary vacuum tube, but as the grid is made more positive, at a certain critical voltage, an

arc strikes between the anode and the cathode, with an accompanying increase in the anode current. The grid then exercises no further control over the anode current, which must be limited by external resistances so as not to exceed the saturation emissive current of the filament. If the voltage across the tube exceeds the disintregation potential of some twenty to twenty-five volts, the cathode will be disintegrated by positive ion bombardment. In the general method for stopping current of a d-c thyratron, the anode is made negative by closing the switch S, Fig. 100, to permit ions to diffuse



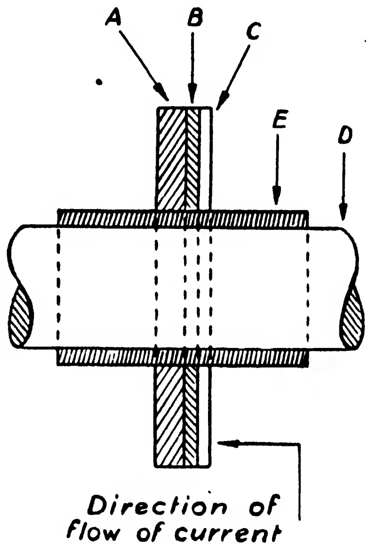
Benwood Linze T-3055 Arc Rectifier and Brenkert "Econarc" Low Intensity Projection Lamp

away from the grid and to restore its control.

A condenser C is connected in series with a resistance R between the anode and the positive voltage terminal. It becomes charged when the current is flowing to the amount of potential difference across the load, which in turn is equal to the supply voltage minus the tube drop. Assuming a supply voltage of 150 and a tube drop of 20 volts, the condenser voltage will be 130 volts. Closing the switch will bring the potential of the right-hand terminal to zero. Simultaneously, the left-hand terminal, which is connected to the anode, suffers an equal decrease because of the high transient impedance

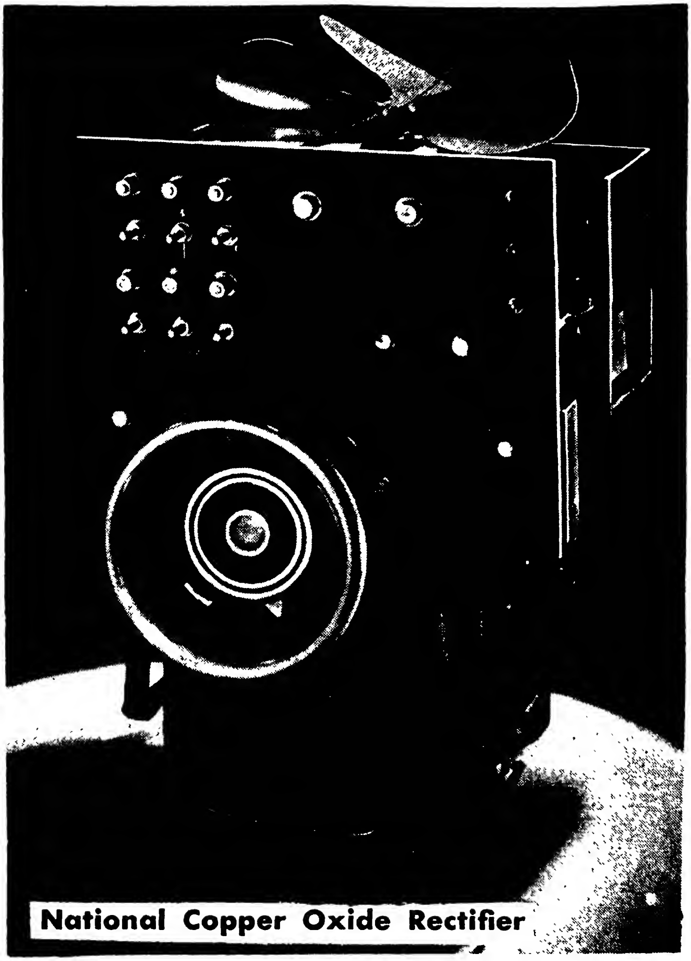
of the load compared to that of the condenser. This reduces the anode potential a negative 115 volts with respect to the cathode and thus stops the flow of electrons and the production of ions. If, then, there is sufficient time for the existing ions to diffuse to the walls of the tube before the anode voltage again reaches plus twenty, the grid will control restarting.

Copper Oxide Rectifier Disc.
(a) Copper disc.
(b) Copper Oxide coating.
(c) Soft metal disc to make contact with oxide surface.
(d) Bolt for assembling disc.
(e) Insulating sleeve.



The arc current of one thyratron can be arranged to alter the grid-bias potential of the next valve in order. Instead of using a switch to ground the right-hand condenser terminal of Fig. 100, the grid of an additional rectifier Fig. 101, is made positive, such action being equivalent to closing the switch, except that the potential falls to 15 volts rather than to zero. The maximum negative anode-potential of T^1 is 100 volts instead of 115. In this way the current is transformed from T^1 to T^2, or can be returned in the reverse direction by making the T^1 grid positive. The same voltage impulse can not cause both tubes to arc simultaneously if there is an arc initially present in one of them. The process

can thus be repeated, subject to the condition that the anodes shall remain negative long enough at each transfer for the ions to diffuse out of the grid spaces.


National Copper Oxide Rectifier

Finally it has been possible to arrange a group of these valves so that when one has started, a cathrode current will pass through the next cathrode resistance in order, decreasing its grid bias a little less negative

than the critical bias necessary for its own starting. In this case, the incoming voltage impulse next applied to all grids increases the grid potential of the valve in question above the critical voltage thus causing it to arc while other tubes still heavily biased are not affected.

Grid-controlled rectifiers can effect relay control due to light action on photo-electric cells, regulate signal and traffic communications, and measure short time intervals accurately. Their regulation of generators and motors, as well as conversion of direct to alternating current is well known.

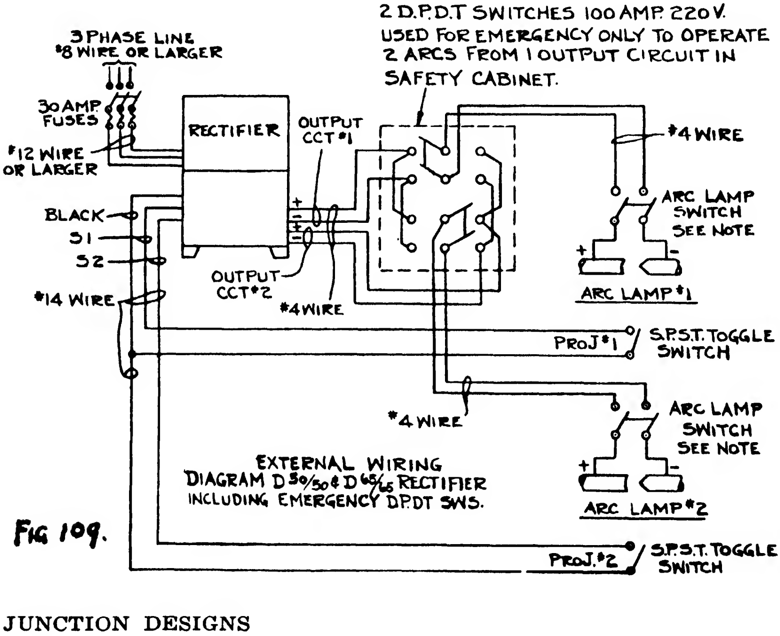
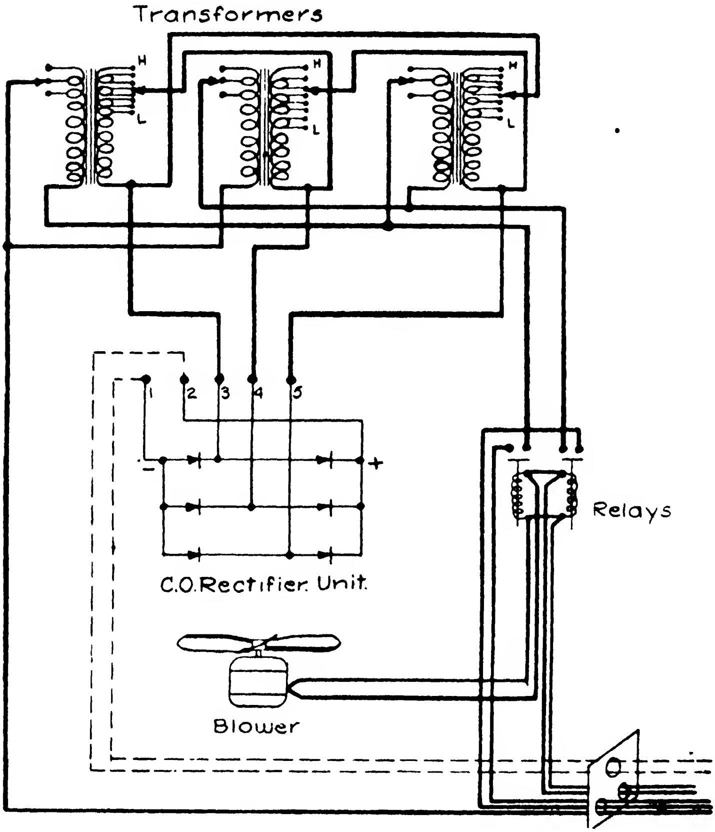


FIG 109.

JUNCTION DESIGNS

The junction type of rectifier has grown out of the deficiencies of some of the above discussed rectifiers for all-purpose radio and motion picture work. In an attempt to relate given materials for a non-mechanical relay, Grondahl first noticed (1920) the asymmetric conductance of a mother copper bearing a cuprous

oxide layer. As the voltage is applied to this device a potential hedge, as it were, is instantaneously set up causing a resistance to electric flow in one direction and an assistance to it in the other, thereby effecting the corresponding high and low resistances.



Rectifying efficiencies as high as 70 percent can be obtained in usual practice with these devices. In general, very high frequencies can be rectified, although some capacitance effect is then said to be encountered. Theoretically, a large number of units can be assembled into rectifiers of any desired rating, the maximum space being a cubic foot to every 4 kilowatts and of weight

equal to twenty pounds per kilowatt. Of the commercial sizes manufactured at present, trickle chargers have a 13 to 6-watt output (1/2-to-1 ampere at 6 volts), while railway signal rectifiers are constructed that have a 200-watt output. In applications where high currents and small size are essential requirements, the so-called dry disc rectifiers furnish a watt output per cubic inch four to five times that of other types.

The limit to current-carrying capacity depends on the

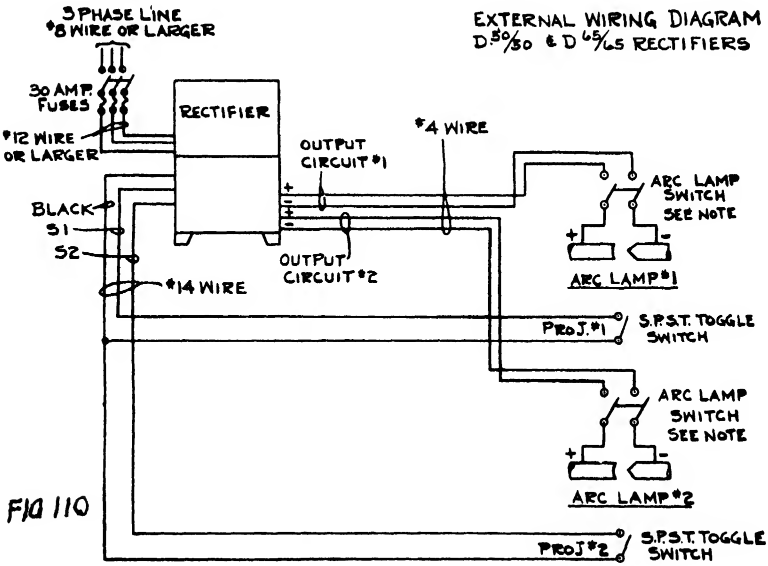


FIG 110

provision for radiating the developed rectifier heat.

MAGNESIUM-CUPRIC SULPHIDE RECTIFIERS

This is a "dry" type rectifier. This unit is to-day being used in the motion picture rectifiers being manufactured by the Forest Manufacturing Company, the unit, however, is manufactured by P. R. Mallory Co.

The magnesium-cupric sulphide rectifier is all metal in construction and contains no liquids, bulbs or moving parts. The rectifier is an assembly of magnesium

discs, cupric sulphide discs and a combination of terminal and radiator plates which assist in dissipating the heat developed in the process of rectification.

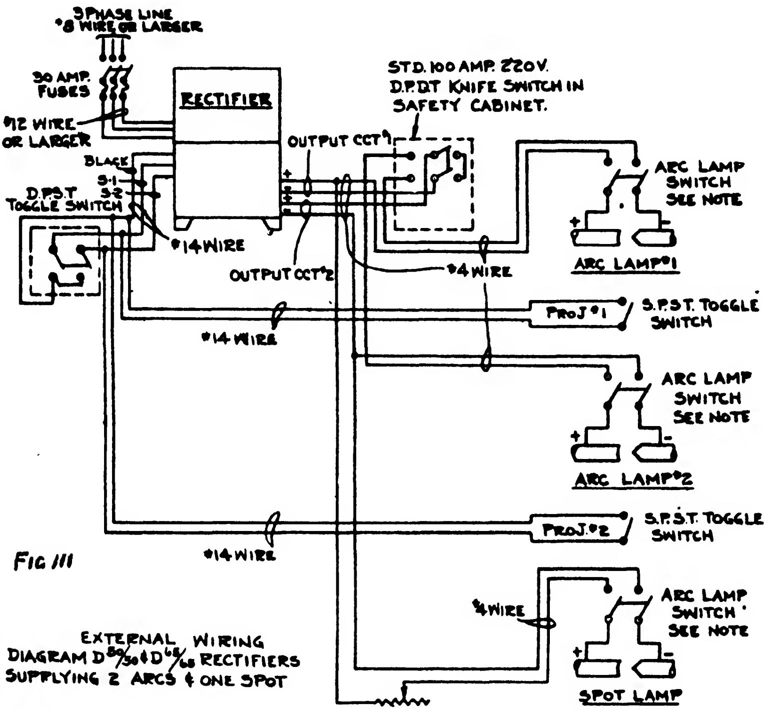


FIG III

FOREST MAGNESIUM-COPPER SULPHIDE RECTIFIER

This is the rectifier constructed especially for motion picture projection work, and employs the Mallory unit, the twin or double type model was originated by Forest. During operation the twin rectifiers work independently of each other, current is completely shut off on that half not in use.

The copper sulphide discs are placed between metallic magnesium discs and metallic non-polarizing discs. These are the important working elements of the rectifier. Heavy radiator plates are placed against the magnesium disc on the one side and the non-polarizing

disc on the other side, to assist in heat dissipation. Electric current flows freely in one direction, from the non-polarizing disc through the copper sulphide disc to the magnesium disc. But the flow of current in the opposite direction, that is, from the magnesium disc through the copper sulphide disc to its non-polarizing disc, is greatly impeded. Consequently, the rectifier serves as a uni-directional conductor or valve, changing alternating current into direct current. The rectifying action occurs at the junction interface, and, being electronic in nature, assumes permanence and stability of the rectifying elements.

FOREST TYPE D-50 AND D-65

These types are for simplified high intensity lamps, they are designed for three phase AC current only, with primary transformer taps arranged for connection to a line of the voltage and frequency stamped on the name plates.

The rectifier consists of one separate and complete rectifying bank within one housing and furnishes 42 to 50 amperes for the 50 type with 6x7 carbons, or 56-65 amperes for the 65 type using 7x8 carbons.

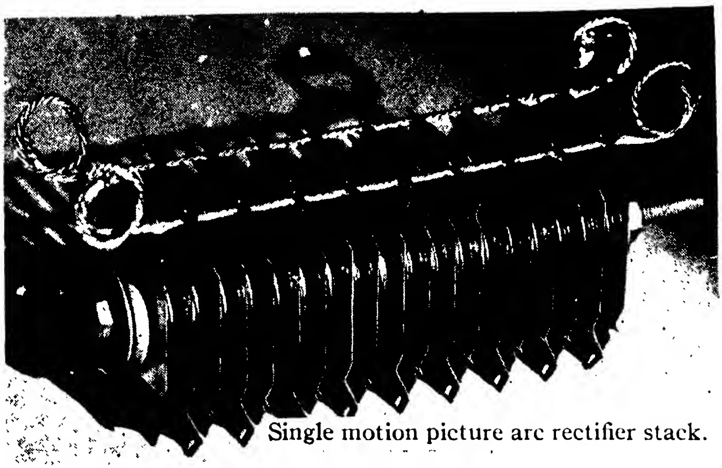
INSTALLATION

The rectifier can be installed in any convenient location in the projection room or in any adjacent room. It is essential however, that the location be well ventilated, preferably in a room with an exhaust fan. The operation of any of the dry type rectifiers in a poorly ventilated room will greatly reduce their efficiency and affect the useful life of the rectifying elements.

Facilities for connection to a three phase current supply should be available, through a suitable fused switch located near the rectifier, as shown in Figs. 109-110-111-112-113-114.

This switch is to be closed to start operation and opened when shutting down, as the primary of the transformer is always connected across the three phase line.

The three phase circuit supplies current for the rectifier bank, the rectifier blower fan and the remote control relay. The rectifier should be connected to the power line and the projector lamp as shown in the diagrams. It is important to observe the rotation of the fan after installation has been completed, to determine if air is being exhausted and not drawn back into the housing. In case air is drawn in at top of rectifier, indicating the fan is running backward, a reversal should be made of any pair of leads in the three phase system.



Single motion picture arc rectifier stack.

REMOTE CONTROL

The rectifier must be operated by remote control, which is accomplished by means of a relay inside the rectifier housing. Operation of the remote control is accomplished by a toggle switch mounted on the side of the housing enclosing the present DC arc switch at the projector, and wired in accordance with the diagram. The present arc switch remains in a closed position and the handle is removed as this switch is no longer used to strike or cut the arc. The remote control toggle switch must be used to control the arc, as in this way, voltage surges are prevented from reaching the rectifier units. This procedure results in increased life of the units and economy in operation.

TRANSFORMER

The rectifier is provided with a three phase transformer, with the secondary wired through a relay and fuses to its bank of rectifying elements. The elements are connected in a full wave three phase bridge circuit.

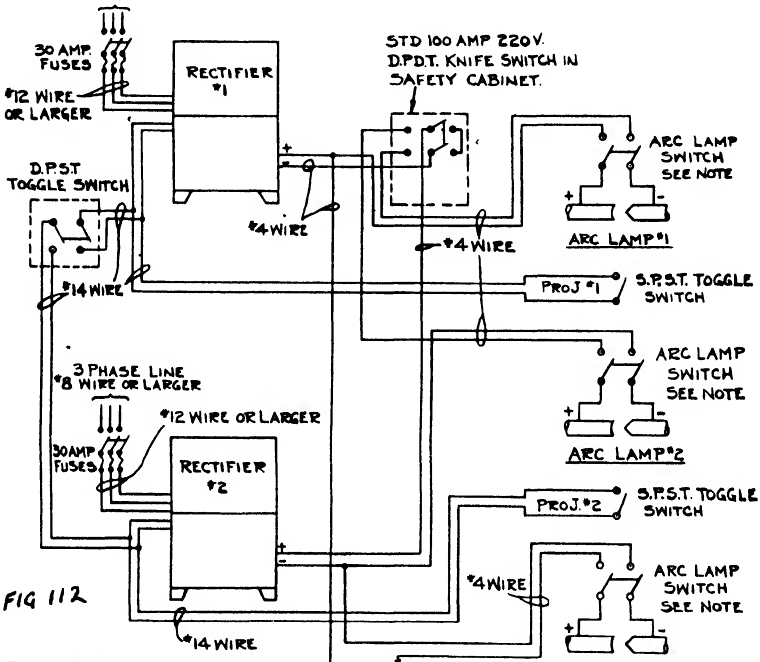


FIG 112

TITLE EXTERNAL WIRING DIAGRAM D-50 & D 65 RECTIFIERS SUPPLYING 2 SUPREX ARCS & 1 SPOT

LINE ADJUSTMENTS

The primary of the transformer is provided with taps to adjust the rectifier to the three phase supply line voltage. These are primary line settings and adjustment is made by moving the terminal strip to the studs nearest the corresponding AC supply voltage.

DC OUTPUT ADJUSTMENTS

Facing the front of the lower compartment of the

rectifier panel, the set of six studs on the upper left, is a set of output control studs for the lamphouse. These sets of six studs have an arrow and are the fine adjustments. The sets of three studs marked "LOW" and "HIGH" with an undesignated medium set of terminals, are the coarse adjustments. The three terminal screws at the top of the transformer panel, are connections to the rectifying units. Removing these three wires disconnects the rectifying units from the circuit entirely.

As the rectifier leaves the factory, the connections at the control studs are set at their lowest positions. If the output current is to be increased, first move the fine adjustment connector strip in the direction of the arrow. When it is is in the last position, and the current output is still too low, bring it back to its original position (opposite to the direction shown by arrow), and move the coarse adjustment connector strip to the next position. Then move the fine adjustment in the direction of arrow. By repeating this process the output current rate can be adjusted to practically any desired value within the rating of the rectifier.

SPOT LIGHT OPERATION

Facilities for operation of a spot light or effect projector are provided by the installation of a double pole, double throw switch, and a double pole, single throw toggle switch. This arrangement connects both single rectifiers in series which increases the output DC voltage only while the amperage remains constant. The toggle switch must be operated in order to operate the relay of each rectifier in order to obtain spot light operation after the double pole, double throw, spot light switch has been placed in spot light operation position.

CLEANING AND VENTILATION

It is essential that both the top and the bottom of the rectifier be kept clean to permit unrestricted intake and exhaust of air. The rectifier should be installed as far as possible from walls and adjacent floor space

kept free from material which will reduce air circulation. Frequent cleaning of the bottom screen will remove accumulated dirt preventing restriction of air intake.

RELAY CONTACTS

The remote control relay requires no maintainance other than an occasional inspection and cleaning of the contacts. This may be done with a No. 000 sandpaper. Make sure that both contacts of the relay make a positive closure with relay in operated position.

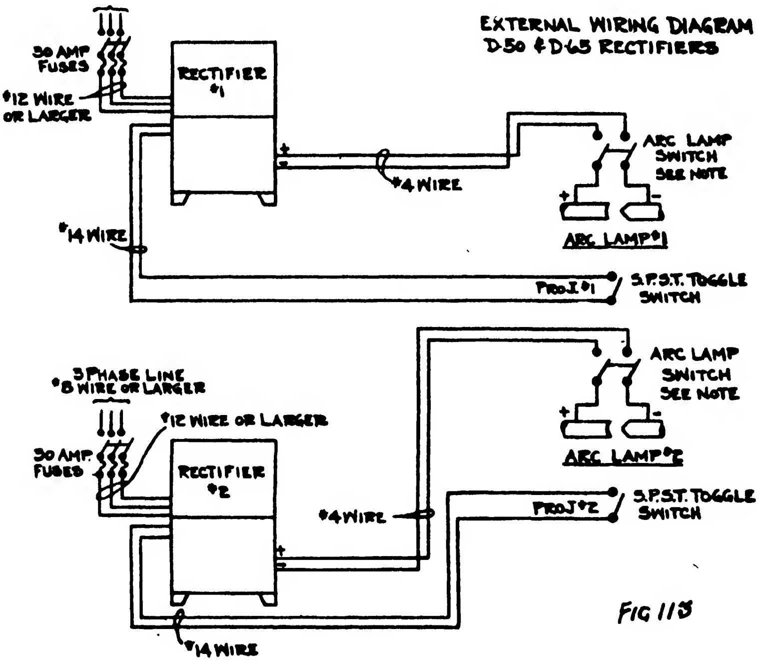
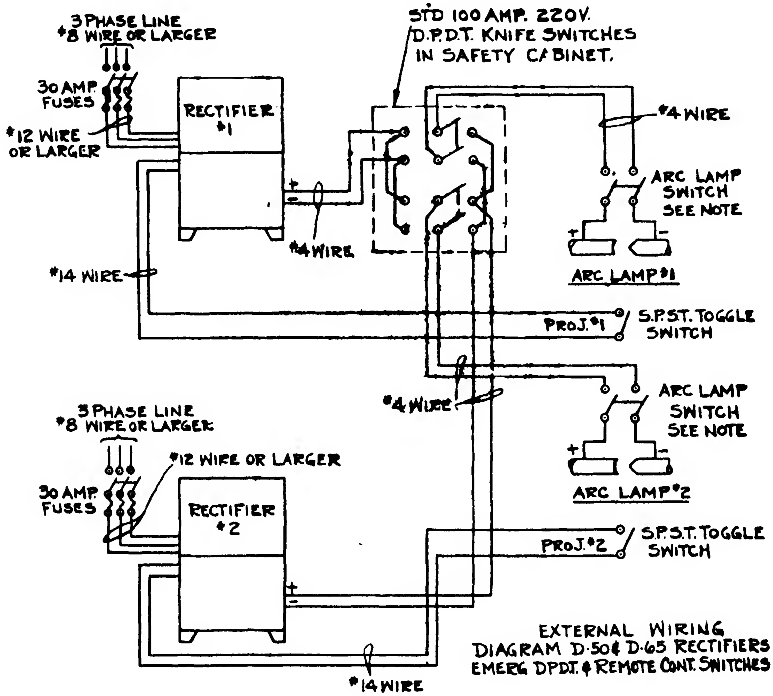


FIG 113

RECTIFIER FUSES

Fuses are located inside the rectifier and are accessible only by removing the upper front panel cover. The rectifier is fused with 80 ampere fuses and under no

condition should the size of the fuses be exceeded. The fuses are connected in the low voltage (secondary)



AC feed to the rectifier bank for the purpose of protecting the transformer in case of rectifying failure.

EXTERNAL FUSES

The three phase AC supply should be fused with 30 ampere fuses. It is important that no larger size fuses be used as a burn out of the rectifier may result. No fuses are required in the DC circuit between the rectifier and the lamphouse arc, and if fuses are now installed, they should be strapped out or replaced with brass tubing in the fuse clips, unless this is contrary to local regulations.

TROUBLES—LOSS OF AMPERAGE

If there is a flicker on the screen with a considerable loss of amperage, making it difficult to hold the arc, it is an indication of a blown fuse inside the rectifier. Under these conditions both fuses should be removed, tested and blown fuses replaced. If fuses continue to blow, it is an indication of a trouble condition with the rectifier bank. This condition may also be caused by an open contact at the remote control relay, or a poor connection at the fuse block or relay inside the rectifier.

TROUBLES—FLUCTUATING AMEPRAGE

A certain amount of amperage fluctuation can be expected in cases where improper carbon trims are used, but in those cases where fluctuations are evident with the proper trim, the cause can usually be traced to a loose or poorly made connection. Under these conditions, an inspection should be made of all connections, including those inside the rectifier, if necessary. Poor connections in the DC arc circuit usually heat and can be located by feeling with the hand. Loose switches, defective fuses, burnt carbon jaws, etc., can also be responsible for this condition. It is advisable to inspect all connections at regular intervals. Inspection should be made of the lamphouse motor feed control. It should be borne in mind that while making the DC amperage adjustment, the carbon gap should be rigidly held within the proper gap setting, set down by the manufacturer. This carbon setting is approximately 5/16 of an inch. The ammeter should now be read for the correct current. It is advisable to make frequent calibration checks of the lamphouse meters with a meter of known accuracy to determine if the reading represents the actual amperage.

TROUBLES—FAN FAILURE

Frequent observations should be made to determine if the blower fan is operating at all times while the rectifier is in use, this should be done particularly on starting the rectifier. In case the fan fails to start, the upper

front cover should be removed and an attempt made to start rotation with the hand while the power is on. If the fan then fails to rotate or is sluggish, the front cover should be left off and a large fan placed in position to blow directly on the magnesium copper sulphide rectifying units. Operation of the rectifier can then be continued until a replacement for the defective fan can be obtained.

TROUBLES—OPERATION OF BOTH ARCS FROM ONE RECTIFIER

In case of trouble in the rectifier whereby no DC output is available, it is possible to operate both arcs from the adjacent rectifier by "stealing the arc." This is accomplished by disconnecting the arc DC leads from the inoperative rectifier and paralleling them with the DC leads of the good rectifier (positive lead connects to positive lead, negative to negative). If DC fuses and switches are installed, the DC leads may be paralleled at these points, but the fuses of the inoperative rectifier should be removed from their clips, or the switch opened to prevent possibility of a feed-back. The handles of the arc switches should be replaced and the remote control toggle switch of the good rectifier left in the operating position at all times. It must be borne in mind to always extinguish the operating arc before striking the incoming arc. The above emergency operation can be accomplished with no loss of time by the use of an emergency transfer.

BRENKERT R-6 RECTIFIER

The Brenkert Light Projection Company of Detroit, who have been manufacturing projection equipment for a great number of years, use the Westinghouse Copper-Oxide disc unit, in the production of the Brenkert R-6.

The rectifier is of unit construction, which allows ready removal, for inspection or servicing, or replacement of the transformers, rectifying element, the fan or the relay. These units are contained in a heavily con-

structed case of welded channel steel frame and heavy steel panels. A panel board on the front of the rectifier contains four sets of binding posts so that proper connection may be made for various incoming line voltages, all connections are made to this panel board, making installation of the rectifier an easy, effective, and positive job.

By means of switching connections to different sets of binding posts, there are ten different sets, it is possible to obtain the exact arc voltage required. Voltage regulations are in one volt steps.

As has already been shown the efficient working of all disc rectifiers depends upon the dissapation of heat generated within the rectifier, and it is all important that the fan be at all times in operation while the rectifier is in use. In the Brenkert Rectifier, they have incorporated an automatic safety device in the shape of a current control switch, which automatically turns the current supply on the rectifier, only when the fan has reached its proper operating speed. Should the fan for any reason become inoperative, this switch will automatically open the rectifier circuit, thus protecting the rectifying units and the transformer from damage. The fan is a ball bearing suction fan, especially designed for this rectifier.

The Brenkert R-6 rectifier is made for line voltages of 190-250, three phase, 60 cycle, and gives 40-50 amperes at arc lamp, or if required a three phase, 60 cycle giving 40-65 amperes at arc. The rectifier can also be obtained for two phase circuits, with arc voltages of 40-50 or 40-65 volts. Rectifiers for other line voltages are available. Fig. 118 shows the Brenkert R-6 with the front and top cover removed, while Fig. 119 shows the rectifier as it looks installed.

GENERATORS

SUPPOSE a magnet and a conductor are placed upon a table in such relationship that when the conductor is moved upward current will flow through it toward the front of the table. When the upward motion of the wire is brought to a stop, the current flow stops. If the wire is moved downward again, current will flow in the opposite direction.

In practice, generators have been found to be more efficient, and easier to construct, if their motion is made rotary rather than reciprocal, as just described. The fundamental principle behind the action of most generators with which the projectionist is likely to come in contact, would involve substitution of a wheel for the table mentioned above.

Suppose a wheel with a rim as broad as the conductor is long. Suppose the conductor to be fastened across the rim of the wheel, and the wheel to be rotated. Then, if the magnet is mounted near the wheel, once in each rotation the conductor may be supposed to move upward past the pole of the magnet, and once in each rotation a pulse of current will be generated, flowing always in the same direction.

In practice, it is found more efficient to use two opposite poles of a magnet, somewhat after the arrangement of the horse-shoe magnet shown in Fig. 220, and to make the conductor a loop of wire, as also shown there. Consider what happens during one complete revolution of the wheel.

As the right-hand side of the loop of wire moves upward past the north pole of the magnet current flows through the wire toward the observer, emerging from the loop at terminal 2. At the same time the left-hand side of the loop is moving downward past the south pole. The direction of the magnetic field is the same in both cases—*i.e.*, the flow of the lines of force is from north pole to south pole—but the direction of motion of

the conductor is opposite on the two sides of the wheel. Therefore, the voltage generated in the left-hand side of the loop will cause current to flow *away* from the observer, and this current will also emerge at terminal 2. The two sides of the loop of wire are therefore essentially in series, and their voltages reinforce one another. This is the condition during Position 1 of Fig. 220.

Now, when the rotation of the wheel has brought it to Position 2, no current flows. The conductor now is moving in the same direction as the lines of force; it does not cut across them. But Position 3 will be seen to be precisely the opposite of Position 1. Here, current in the right-hand side of the loop flows toward the observer, precisely as before, but because the loop has reversed its position, the current now emerges at Terminal 1. Current in the left-hand side of the loop flows away from the observer, exactly as before, and, exactly as before, also emerges from Terminal 1.

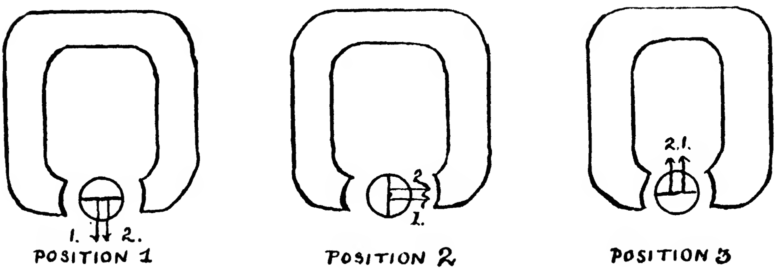


FIG. 220

Now, if terminals 1 and 2 were fastened each to one metal ring, which could rotate with the wheel, and if an external circuit were connected by means of sliding contacts to each metal ring, then, as the wheel continued to rotate, each ring would be alternately positive and negative,—that is, the current would emerge first at one ring, and then at the other, as the loop of wire changed position. In consequence, an alternating current would flow in the external circuit.

COMMUTATION

Fig. 221 shows how a direct current—a current flowing always in the same direction, can be drawn from a machine in which an alternating current is generated. Fig. 221 is Fig. 220 simplified. The poles of the magnet, but not the entire magnet, are shown; and the loop of wire is shown without any means of rotating it. These are mere simplifications in the drawing to help the reader concentrate his attention on the means by which current is taken from the loop.

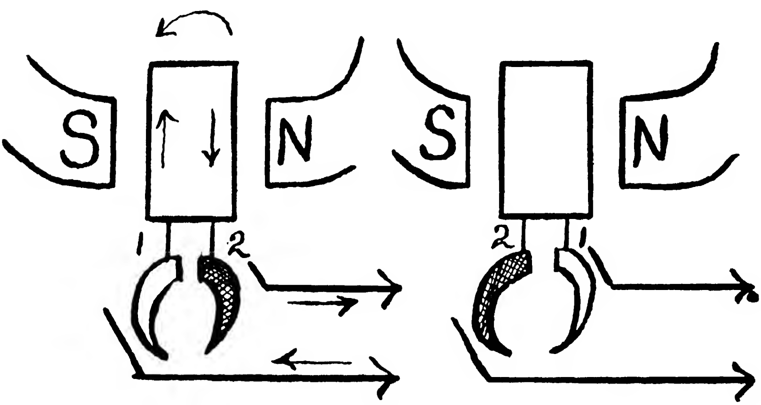


FIG. 221

It will be seen that in Position 1 the current flows toward the observer through Terminal 2 and away from the observer through Terminal 1. In Position 2 precisely the opposite is the case. The current flows toward the observer through Terminal 1 and away from him through Terminal 2. But each terminal is now connected to an insulated segment of the metal ring through which current is drawn off. Segment 2 has been darkened in both cases to make clear that it has reversed its position in precise time with the reversal of the direction of flow of current in the loop. Consequently, the current in the external circuit always flows in the same direction, as the arrows show.

The power drawn from a machine based upon this principle of generation and of commutation can be increased by increasing the number of loops. Additional commutator segments will then be needed, and instead of each segment being a complete semi-circle, as in Fig. 221, it is customarily only a very small portion of a circle. The principle of action remains the same.

The Voltage in Each Loop

Since the two sides of the loop act as if they were in series with each other, the voltage developed by any one loop may be increased by giving the loop several turns, as shown in Fig. 222. The EMF generated in each turn of the wire shown in Fig. 222 will add to the EMF developed in all the other turns, with the net result that the potential difference developed at the commutator segments will be increased. A single loop in practice may consist of one, two, or several turns of wire.

The Arrangement of the Loops in the Armature

The loops of wire in which current appears are commonly referred to as the armature; and in practice an armature is customarily made up of a number of loops, each of which, again, may contain a number of turns. The loops will be so linked with each other that (depending upon the way in which the armature is wound) their effective circuit will be that of a number of independent generators connected either in series or in series-parallel. As the armature revolves the loops constantly take each other's places, and therefore the precise relationship between any one loop and its neighbors alters from moment to moment, but since these changes balance each other the effective circuit and the overall action of the armature as a whole remain always the same.

The loops are wound upon an iron core; the most common methods of arranging the wires in use today known as lap winding and wave winding. In the lap winding each coil spans only a relatively short distance along one side of the armature; in the wave wound armature the two ends of the same coil are

brought out at opposite sides of the core. In either case, however, there is continuity throughout the armature circuit, with two wires connected to each segment of the commutator—the end of one loop and the beginning of another. In consequence, an open or a grounded loop cannot be found by using a test lamp or a pair of headphones upon the commutator. Since continuity exists throughout the armature the entire commutator will be grounded whenever one loop is grounded, and the offending member can only be found by using a milliammeter or a sensitive ohmmeter or voltmeter to detect which segment has

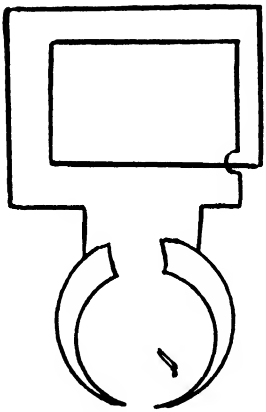


FIG. 222

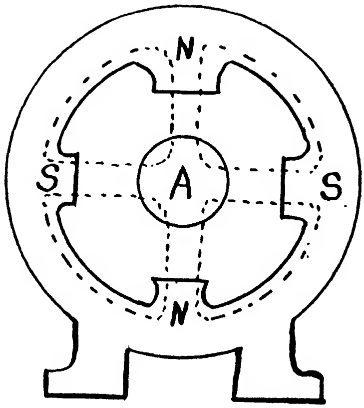


FIG. 223

the smallest resistance between itself and ground. If this is not done the coils must be disconnected from the commutator one at a time and tested individually with a lamp, buzzer or headphones. The same holds true if a loop is open. It will be short-circuited by its fellows. The short-circuit, however, will have a higher resistance than the loop itself, and so can be detected by a suitable meter; if none is available the coils must be disconnected from the commutator and tested singly. Any single coil may terminate either at two adjoining segments of the commutator or at two widely separated segments, depending on the type of winding used in the armature.

THE CONSTRUCTION OF THE ARMATURE

The core is made of "laminated" iron—that is, built up of sheets of iron sufficiently separated from each other to prevent the creation of large eddy currents. The surface of the core is, in most armatures, slotted, and the turns of wire rest in the slots.

Consider the loop of wire shown in Fig. 221. Most of the space between the poles of the magnet is shown there as filled with air, and the magnetic flux would be weak accordingly. If the same loop of wire were wound around a solid iron cylinder, most of the space between the turns would be filled with a superior conductor of magnetic flux, and the strength of the field, and consequently the amount of power generated in the coil, would be greatly increased. (It will be remembered that one volt is generated when the wire cuts a flux strength equal to 100,000,000 lines of force in one second of time.) This is the reason for using iron in the cores of armatures. For the same reason, and also for the sake of mechanical safety, slots are provided on the surface of the iron, in which the coils can rest below the surface of the core.

By sinking the coils beneath the surface of the core, in slots cut into the iron, the core can be brought still closer to the pole pieces of the magnet, and the air length of the magnet path can be still further reduced. Moreover, since the coils are thus protected, the clearance of the machine can be made less; if the bearings wear and the iron of the armature brushes lightly against the iron of the magnet no great harm is done; whereas if the coils of wire were exposed on the surface of the core, they would be torn off when the bearings wore far enough to permit any slight friction between the rotating and the stationary parts of the machine. A generator in which the coils are placed on the surface of the core must be built not only with enough clearance to prevent the coils from rubbing the pole pieces when the machine is new, but also with enough clearance to allow for wear in the bearings as it ages. The efficiency of such a machine is therefore less than that of one with a slotted commutator.

In addition, placing the coils in a slot in the surface of the core, and hooking the top of the slot back over the coils until they are almost entirely closed in (which is done in many machines) helps prevent the wire tearing loose by centrifugal force when the speed of the generator becomes exceptionally high.

When the current to be generated is large, very often square bars of copper, rather than wire, are placed in the slots. There may be several such bars, or several wires, as the case may be, in each slot. Each wire or bar is of course insulated.

The coils are commonly taped down with flat tape, to prevent them from creeping or moving because of centrifugal force when the armature rotates. Binding wire may be used in place of tape. Depressions are commonly sunk in the iron of the core to make place for such binding tape or wire, and allow the air gap between core and magnetic poles to remain as small as possible.

Construction of the Commutator

Each small portion of a circle of which the commutator is composed must be entirely insulated. Insulation is placed under each segment, and between all segments. The insulation used is, in almost all modern machines, sheet mica. No other insulation has been found that is as little affected by heat or by sparking (which occurs when the sliding contact with the commutator is less than perfect) or that is equally elastic when the copper segments expand and contract with changes in their operating temperature.

The commutator is under great strain of centrifugal force, which tends to distort its shape. Both copper segments and the insulation between each pair of segments must be very firmly held in place. This is commonly arranged for by means of wedge-shaped clamping rings which push from each side into wedge-shaped recesses in the segments some distance below the surface of the commutator.

In spite of all efforts, however, the insulation between neighboring segments will sometimes creep up, as a result of

centrifugal force, until the mica is higher than the copper, and contact is made imperfect. Future allowance is sometimes made for this by "undercutting" the mica—that is, trimming it down till its level is slightly below that of the copper.

The Sliding Contacts

A sliding contact to the commutator, through which current generated in the armature can flow to an external circuit, must be softer than the copper of the commutator, if the latter is to be spared excessive wear. "Brushes" of copper are used for this purpose. They take the wear, and are so mounted that they can readily be changed when their curved faces, which fit the curve of the commutator, are worn out of their proper shape.

The brush will span two or more segments of the commutator. When the wiring of the armature is such that the ends of any coil are brought out to adjoining segments the brush is so placed that when it short-circuits a coil that coil is at that moment in a "neutral" position (Position 2 of Fig. 220) in which no current flows. Otherwise the coil might burn out through excessive current flow. Current at that moment is appearing in other coils, and reaches the brush because there is continuity of circuit throughout the entire armature.

Brushes are often so mounted that they can be shifted around the circumference of the commutator. Shifting the brushes is one means of stimulating a generator when, for reasons to be explained later it refuses to "build up."

The Magnets of the Field

Figs. 220 and 221 show simple steel magnets, such as may be used in very small generators for automobile ignition or other light purposes, but where heavy current is required the steel magnet does not afford sufficient flux, and the electro-magnet must be used.

Any conductor is in a sense an electro-magnet, but the magnetic force is concentrated when the wire is wound in the

form of a coil, and the flux is further increased when an iron path is provided for it. One end of an iron core surrounded by a coil of wire carrying current will be the north pole; the other end will be the south pole, according to the direction in which the current moves around it.

The horseshoe magnets in Figs. 220 and 221, therefore, could be replaced by two coils of wire in which current is flowing in opposite directions, so that one will serve as north, and the other as south pole. The arrangement of the common type of 4-pole generator is indicated in Fig. 223. "A" represents the armature, and the magnetic circuit is across the small air gaps, through the iron of the armature to the nearest opposite pole, and back through the iron frame of the machine, as shown by the dotted lines. Each pole shown in the drawing, of course, consists of a coil of wire wound around an iron core.

Field poles are often of laminated construction. Although steady direct current flows through them, it will be remembered that the wires of the armature also carry current, which has been induced in them by the action of the generator. Now this current in the armature, no matter how it got there, is still current, and therefore magnetic, and capable of inducing eddy currents in the core of the field poles. These poles, or at least those portions of them which are nearest the armature, are commonly laminated to minimize that effect.

It will be seen that any single wire in the armature of Fig. 223 is in a neutral position (Position 2 of Fig. 220) when it is located between any two field poles, for then it is moving in the same plane as the magnetic flux, and is not cutting across the flux path. When it is opposite any pole, the wire is cutting through the magnetic flux, and current is generated in it.

In some generators, especially those called alternators or inductors, which will be described later in this chapter, the current for exciting the field coils is drawn from an external source—another and small generator, or sometimes from batteries. Those generators with which the projectionist is most familiar, however, such as the generators most commonly used for arc supply, themselves provide the current with which the

field coils are activated. This current is drawn from the armature, by means of any one of three circuit arrangements, and therefore the armature must begin to generate power before the field poles begin to be activated by current in their coils, and so become electro-magnets.

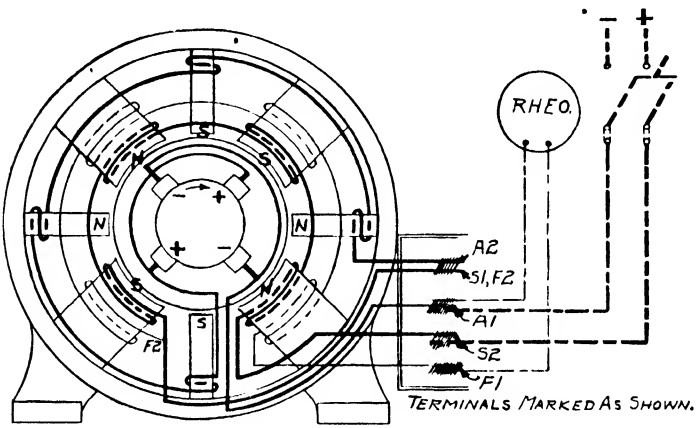
Residual Magnetism

If the field poles were made of hard steel instead of soft iron, they would become permanently magnetized when current had once passed through their coils, exactly as a steel screw-driver can be magnetized by placing it in the center of a coil of wire carrying direct current. The field poles are in fact soft iron, which is only temporarily magnetized by the presence of current, and in which the particles resume their original, non-magnetic position as soon as the stress of the ether which caused them to fall into a magnetic arrangement is withdrawn. However, a relatively small proportion of the particles of even the softest iron will remain in magnetic position and in consequence a minute amount of magnetism will remain in the field pieces when the current through them is discontinued. If the armature is then caused to rotate, an extremely weak current will be generated.

A portion of this very weak current being permitted to flow through the field windings, their magnetic strength will be greatly increased; an increased current will appear in the armature, and this, fed back into the field coils will still further increase their magnetic flux and in turn still further increase the armature current. The generator, as it is called, "builds up." The limit of the process of building up is reached when the flux through the iron of the poles becomes so great that further increase in the field current no longer causes a proportionately large increase in magnetic power.

Field coils can be connected to the armature (at the brushes) according to three circuits. They may be placed in parallel with the armature, and therefore with the external load. They may be wired in series with the armature, and therefore also in series with the external load. Or they may be a double

winding on each field pole, one in series and the other in parallel with the armature. Such a machine is called a compound-wound generator, and is the type with which the projectionist will be most often concerned. An understanding of the reason for compounding, or using double field windings, will be plain if the action of the two other types—the series and the shunt generator,—is analyzed with respect to the voltage developed at their brushes under varying conditions of load.



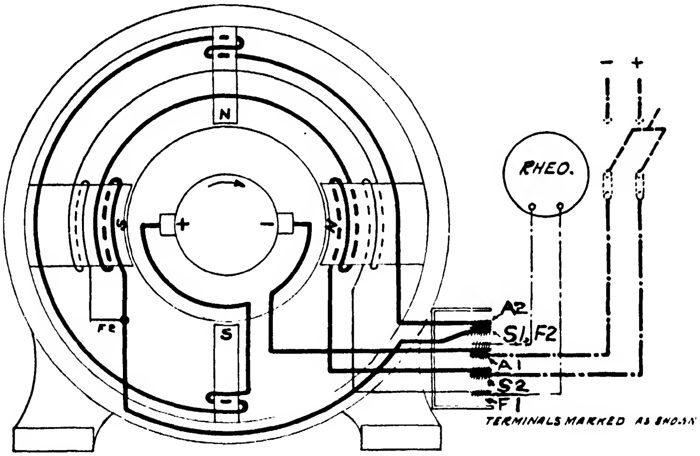
4 Field Poles and 4 Inter Poles, Compound Wound Generator with Field Rheostat. Polarity Shown for Clockwise Rotation Facing Commutator End

The Series Generator

In this type of generator the field windings will be in series with the external load, and therefore no current will flow through the field until the external switch is closed. When this is done the generator "builds up." When full power is reached the current flowing will depend partly on the voltage generated—1 volt fo. every 100,000,000 lines of force cut by a conductor in one second of time—and partly upon the resistance of the circuit. The external load, the field coils, and the armature coils, connected in series, make up the circuit. The

external load, taken as a whole, may of course consist of any arrangement of resistances, whether in series, parallel or series-parallel. The total effective resistance of any such arrangement, taken as a whole, is what is known as the "external load."

Now, current is the same in all parts of a series circuit. The current that flows through the external circuit also flows through the field windings and provides the magnetic flux. Whenever the current in the external circuit is changed, the current in the field windings will change. And, since the



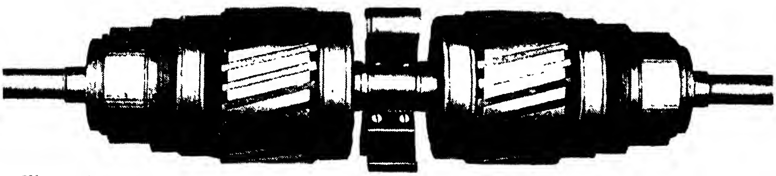
2 Field Poles and 2 Inter Poles, Compound Wound Generator with Field Rheostat. Polarity Shown for Clock-wise Rotation Facing Commutator End

voltage of the machine depends upon the number of lines of flux cut per second, the voltage of the series generator will change whenever there is any alteration in the amount of current drawn from it.

Whenever the total effective resistance of the external circuit is increased, whether by adding resistance in series or by removing resistance from a parallel connection, the current flowing will, by Ohm's Law, decline; the flux generated at the

field poles will decline accordingly, and the voltage across the brushes of the generator will drop. When the total effective resistance of the external load is decreased, whether by removing series resistance or through providing additional paths for the current by adding resistance in parallel, the current flowing, the field flux, and consequently the brush potential of the generator will rise. (This, of course, assumes that speed of the generator remains constant; the decrease in voltage through weakened flux may be partly offset if the means of driving the generator are such that weakened flux resistance permits it to increase its speed of rotation.)

With the series generator, then, up to the limits of the power the machine can develop, *increased* current means *increased* voltage across the brushes; decreased current means decreased voltage at the brushes.



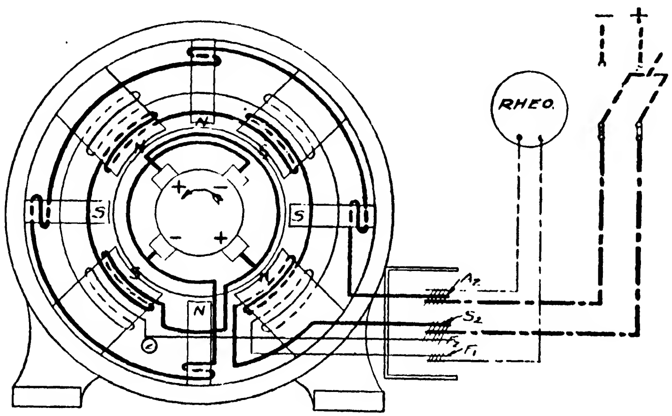
Illustrating Armature of 2-Bearing Double Generator for Suprex Carbon Arcs

The Shunt Generator

In this machine, the field windings are also commonly in series with each other, but as a group they are connected in shunt across the terminals of the armature. The current flowing in the field circuit, therefore, depends entirely upon the brush voltage and the field circuit resistance, and is not the same as the current flowing in the external circuit. This type of generator will "build up" regardless of whether the external circuit be open or closed.

The action of the shunt generator, however, when the current drawn from it is increased, is opposite to that of the series generator.

With the shunt-wound machine, the flux force remains nearly the same regardless of load, and therefore the total voltage generated *in the armature coils* remains nearly the same regardless of load. But, if the current flowing is increased, by variation of the external load, then, since all current flowing through the external load must also flow through the armature, the voltage drop across the armature is increased. This follows from Ohm's Law. Since the resistance of the armature remains always the same, then if more current flows through



4 Field Poles and 4 Inter Poles, Compound Wound Generator with Field Rheostat. Polarity Shown for Counter Clockwise Rotation Facing Commutator End

it, more voltage is needed to make it flow, and the voltage drop across the armature must be proportionately greater. Therefore, although the voltage generated *in the armature* remains constant, a greater proportion of the voltage is used up within the armature itself when the current flow is increased, and the brush voltage declines accordingly.

With the shunt wound generator, therefore, *increased* current means *decreased* voltage across the brushes, and vice versa; the reverse of the action of the series-wound type.

The Compound-Wound Generator

Generators are made to deliver nearly constant voltage, regardless of all reasonable variations in the amount of current flowing through the external load, by combining the series and the shunt types in one machine, known as a compound-wound generator. The amount of compounding—that is to say, the relative strengths of the series and of the shunt fields, under all normal operating conditions—must be carefully calculated to insure that neither effect predominates, but that in the normal use for which the machine was intended they balance each other very closely.

Commonly, both series and shunt windings will be placed on the same poles. The direction of current through each must be the same, so that the magnetic power generated by one will assist and not oppose the flux generated by the other.

With a generator of this type, when the current flowing through the external load is increased, the resulting increase in voltage drop within the commutator will be compensated by the increased flux created by the series winding. When the current flowing through the external circuit is lessened, the decrease in the flux generated by the series winding is compensated by the decreased voltage drop within the armature.

The steadiness of the terminal voltage delivered by any compound-wound generator will depend upon the exactness of the balance between the conflicting forces, and this in turn will not be accurate unless the circuits with which the machine is used are nearly similar to those for which it was designed. Many projectionists who have changed their arc lamps but not their generators find their machines either over- or under-compounded for the new load placed upon them.

In the case of almost all compound generators, as indicated above, the actual work of developing current is done largely by the shunt field; the series field acting primarily as a regulator.

Controlling Generator Output

A rheostat placed in series with the shunt field, and there-

fore commonly known as a field rheostat, is often used to control the voltage of the generator independently of the compounding. This rheostat acts to vary the resistance of the

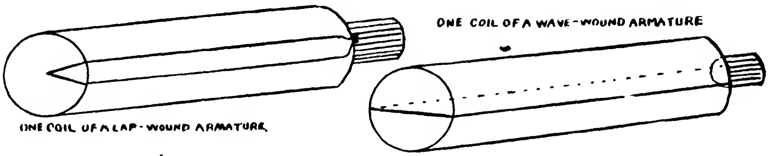


FIG. 224

shunt field circuit, and therefore amount of flux created by it. The flux strength, in turn, controls the voltage developed in the armature.

Another method of controlling the voltage of a generator is to vary the speed of the motor that drives it. This, independently of the magnetic strength of the field poles, will vary the *amount* of that strength (the number of lines of force) which the conductors of the armature cut in one second of time.

Multi-Pole Generators

A four-pole generator is shown in Fig. 223. The arrangement of the poles should be compared with that shown in Fig. 220. In Fig. 223 any single conductor upon the armature does in 1/4 of a revolution of the armature what the conductor in Fig. 220 does in one full revolution—that is, passes both a north pole and a south pole. For any single conductor in the armature of Fig. 223 the neutral point (Position 2) is halfway between any two of the poles, but all of the conductors are not in a neutral position at the same time.

If the armature of Fig. 223 is lap-wound (Fig. 224) so that each coil of the winding lies along one side of the core, the generator will have as many brushes as there are poles. If wave-winding is used, and the two ends of each coil terminate at opposite sides of the commutator, the generator will have two brushes only, regardless of the number of poles.

Alternating Current Generators

The preceding portions of this chapter have described only direct-current generators—those having commutators. It has been seen that alternating current is developed in the armature windings of such generators, but is converted to direct current at the commutator. Each segment of the commutator changes its position, relatively to the brushes, in time with the change in the direction of the current flowing through it, so that the direction of the current through the brushes is always the same. The direct current flowing off through the brushes is not perfectly steady. The relative areas of copper and of mica bridged by any brush vary as the commutator turns, resulting in a "ripple" in the strength of the direct current delivered. Although it is of no practical importance for most uses to which current is put, a ripple of this kind must sometimes be filtered out if the current is to be used in connection with a sound system.

The type of direct current generator that has just been described in some detail will serve as a source of alternating current if the commutator is dispensed with, and if the armature so wired that the ends of each coil are brought out to a pair of slip rings. The brushes will then rest upon these slip rings, instead of upon a commutator, and the current flowing through them will continuously reverse its direction as the coils of the armature change position.

This arrangement, however, is not, for many purposes, the best that can be obtained, and is not the only arrangement used.

In one common type of alternator the field coils are mounted on the rotating unit, and the armature is wound as a stationary ring around this unit. That form of construction is used especially in large machines, where the armature current is conspicuously heavier than the field current. Since the armature is stationary and only the field revolves, the sliding contacts carry the weaker of the two currents, with consequent minimization of brush trouble.

In another type of alternator, known as an inductor, neither the field and the armature windings rotate. The rotating

element is a toothed iron or steel wheel, each tooth of which, as the wheel rotates, passes through an air gap in a flux path. The strength of the flux is greatest when the air gap is nearly closed by intrusion of the metal tooth, and is least when the gap is clear. Although with this arrangement neither field nor armature move, current is generated in the latter. The action may be thought of as a motion of the lines of force, which appear and disappear as the flux strength varies. The lines of force cut the conductor, instead of the conductor cutting the lines of force.

The induction generator may be described as very roughly similar *in construction* to the generator shown in Fig. 223 assuming the field windings to be excited by alternating current. There is no sliding contact, the rotor windings constituting closed circuits. Considering any one field pole, that end of the pole which is nearest the rotor reverses its magnetic polarity from moment to moment, as the direction of the current in its windings reverses. An induced current flows through the windings of the rotor, which in consequence are surrounded by magnetic fields of their own. If mechanical power is applied to cause the rotor to revolve at more than a certain critical rate of speed the lines of force of the rotor's magnetic fields will cut the windings of the stator so rapidly that they will generate a counter-E.M.F. stronger than the voltage of the exciting E.M.F., and the machine will function as a generator, current being drawn from the stator windings. The counter-voltage thus generated in the stator will continue to induce current in the rotor windings, and the magnetic field of the rotor will in turn continue to induce current in the stator, the action continuing as long as the applied mechanical force continues to drive the rotor at the required rate of speed.

The action, however, is more intricate than this very brief and inadequate description may perhaps indicate, and may be more fully understood after the operation of an induction motor has been described, in a subsequent chapter. Much the same may be said of the accounts given above of the action of other forms of alternators.

MOTION PICTURE GENERATORS

WESTINGHOUSE MOTOR-GENERATOR

PROJECTION equipment of the multiple arc type is the accepted standard of modern theater practice. The arc is supplied with direct current by a motor generator which can be furnished to operate from an AC or a DC power circuit. The starter for the motor may be an automatic or a manual type for either full voltage or reduced voltage starting.

A ballast rheostat is used with each projection machine and with spotlights or other accessory equipment requiring direct current. The control panel has a voltmeter and an ammeter mounted upon it to inform the operator of the power being supplied by the motor generator set.

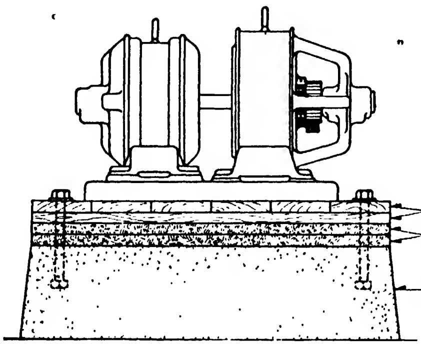
The handle of the generator field rheostat is located on the control panel to enable the operator to make desired current adjustments of the generator while watching the ammeter and voltmeter.

UNPACKING

When uncrating the equipment protect the various units against severe shocks and blows, especially if the temperature of the air is very low. Do not remove the blocking between the generator and motor frames until the set is finally installed at its permanent location. Furthermore, these sets should never be moved from their permanent location unless suitable blocking is placed between the motor and generator frames. This is important so as to prevent bending the bearings out of alignment. Be sure to protect all the equipment from moisture and make certain that all windings of the motor and generator are dry before subjecting them to operating voltage.

LOCATION

All of the electrical equipment should be finally installed in a clean, dry well ventilated place and in such a manner as to be easily accessible for inspection and cleaning. The room or enclosure for the equipment should be sufficiently well ventilated so that the air temperature will never be in excess of 104° Fahrenheit.



FOUNDATION

The foundation should be of such a height that the bottom of the bed-plate will be approximately two feet above the level of the surrounding floor. Motor-generator sets used with motion picture equipments are provided with non-self-supporting bases, making a rigid foundation necessary to keep the set in alignment. If, however, a spring support is used, the spring must be of such a strength and so placed as to allow no undue stresses in the bedplate. To prevent the magnetic hum and vibration of the set being transmitted to the surrounding supports such as floor and walls of the building, it is desirable to build a vibration and sound-absorbing base.

Such a base may be constructed readily with solid planking two inches thick and layers of solid cork each layer two inches thick. The supporting foundation should preferably be

made of hollow concrete. The cork should be placed in two layers on the concrete foundation. On top of the cork should be placed the plank frame constructed of the two layers of two-inch plank. The planks of one layer should be laid at right angles with the planks in the other, both layers to be bolted or nailed together securely. The motor generator may then be mounted on the plank frame and, if desirable the bedplate may be bolted down to the plank frame as desired, heavy felt may be substituted for the cork but cork is much more resilient and will remain elastic indefinitely, whereas felt will not.

When constructing the foundation and sound-absorbing base it is essential that the top of the plank platform be made level so that the oiling system of the motor-generator will not fail after the set is installed.

For installations where it is not expedient or advisable to build such an elaborate foundation, very satisfactory results can be obtained by mounting the bedplate on fairly heavy helical compression springs. These springs should be sufficiently long to raise the bottom edge of the bedplate one-half inch above the floor. The upper ends of the springs should be securely bolted to the under side of the bedplate by suitable bolts. These springs should be sufficiently heavy to keep the set from being "wobbly," and yet not too stiff, so as to defeat their purpose.

At least three or four springs should be placed under each side of the bedplate. These must be so located that the weight of the set will be evenly distributed. When this condition is reached the revolving parts will run smoothly and without excessive friction in the bearings.

Continuous Picture Service

Multiple or parallel arc equipment is required for installations where two or more motion picture projection machines are to be operated alternately for "change over" or "continuous picture service." For the latter service one projector is warmed up for a period of approximately one minute as the other projection machine is finishing its reel.

Installation

The motor generator set may be installed in the projection room or in an accessible location as near the room as possible.

Control Panel

The control panel should be installed in the projection room either between the two projection machines or directly to the rear of them. It is essential that the control panel be so located that the operator can readily read the current and voltage and reach the rheostat handle to make current adjustments.

Field Rheostat

The electrical characteristics of the generator field rheostat must be suited to the generator used. After the generator capacity is determined, the rheostat can be ordered accordingly.

Ballast Rheostats

The ballast rheostats should be installed in or near the projection room. They should be mounted in such a manner that a current of air is free to circulate vertically between the grids.

Motor Starter

The starter should be mounted near the motor. When an automatic starter is used the generator set can be controlled from a remote position by means of a push button.

Wiring and Connecting Motor-Generator Type CS Polyphase Motor

"Three Phase, (Three Terminals)—Connect any lead to any motor terminal. To reverse the direction of rotation, interchange any two leads.

"Two Phase, Four Wire (Four Terminals)—Connect the

leads from one phase to motor terminals T1 and T3 and the leads from the other phase to motor terminals T2 and T4. To reverse the direction of rotation, interchange the leads of one phase.

"Two Phase, Three Wire (Four Terminals)—Connect the two outside leads to motor terminals T1 and T2 and the common lead to T3 and T4. To reverse the direction of rotation, interchange the two outside leads.

"Connection of Motor with More than Standard Number of Terminals—Refer to the connection plate on the motor or to the connection sheet filed in the instruction envelope."

Lubrication

Before starting, fill the oil reservoirs with the best quality of clean dynamo oil; overflow plugs must always be kept open. The oil should be withdrawn occasionally and fresh oil substituted. The old oil can be filtered and used again.

Starting the Motor-Generator

After the apparatus is properly installed and all wiring is correctly connected, close all the switches in the generator line and also that short circuiting switch on each projection machine. Turn the contact arm of the field rheostat to the extreme position marked "lower voltage," and then start the motor.

Type CS Polyphase Motor

See that the auto-starter handle is in the "off" position. Close the circuit-breaker, if one is used, then close the main switch. Move the auto-starter handle from the off to starting position. When the motor attains practically full speed, move handle of auto-starter to running position. Do not leave the auto-starter handle in starting position.

If an auto-starter is not required, the starting switch must be thrown to the starting position until the set operates at al-

most full speed and then the switch may be thrown to the running position.

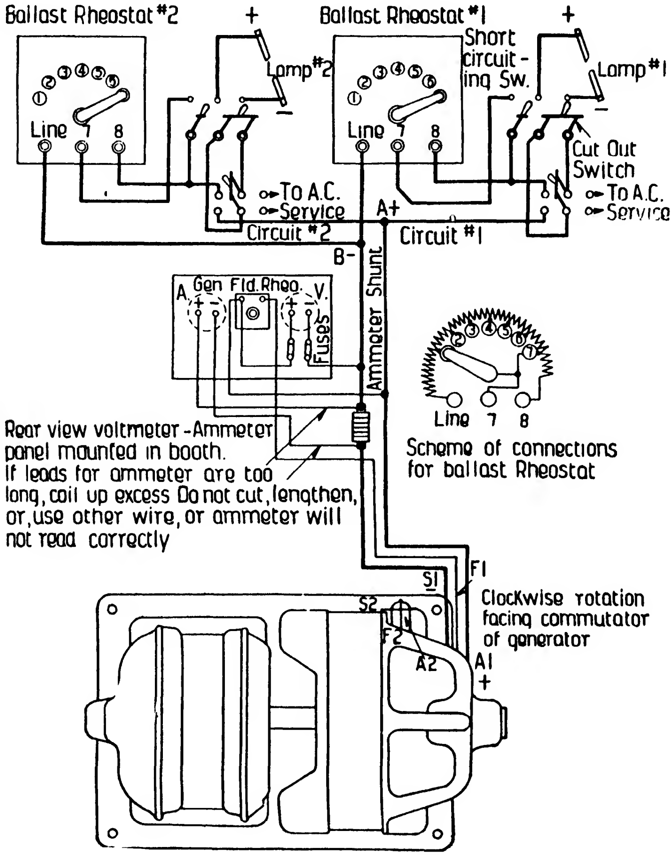


Diagram of Connections Series Arc Equipment

Type AR Single-Phase Motor

Close the line switch. The motor starts as a repulsion motor with current flowing through the brushes and commutator. At nearly full speed, a centrifugal governor inside the armature automatically short-circuits the armature windings,

thus causing the motor to run as a squirrel-edge induction motor. The brushes are thrown off by the end thrust of the armature. If the motor does not come to full speed, which is shown by continued sparking at the brushes, the motor is overloaded and will overheat. Apparently there is an overload on the generator. Look over the generator circuit and make sure that all load is removed by opening all cut-out switches.

Type SK Direct-Current Motor

To Start Motor—See that all instructions for connecting and installing the motor have been complied with and that the handle of the starter or controller is in the "off" position. Close the line switch or circuit-breaker and move the starter or controller handle step by step to the running position. Motors of less than 10 horsepower can usually be brought to full speed in 15 seconds, and the larger motors in about 30 seconds; the time, however, varies with the torque required. If the motor does not start when the third step is reached, first open the line switch or circuit-breaker, then move the handle of the controller to the "off" position, and look for overload or faulty connections.

Inspection of Oiling System

After the motor-generator is started raise the covers of all bearings and see that all oil rings are rotating properly and carrying oil up on the journals.

Stopping the Motor Generator

Type CS Polyphase Motor—Open circuit-breaker or main switch. Move the handle of auto-starter to the "off" position. If neither circuit-breaker nor main switch is used, the auto-starter may be used to close and open the main circuit.

Type AR Single-Phase Motor

To Stop Motor—Open the line switch or circuit-breaker.

Type SK Direct-Current Motor

To Stop Motor—When a starting rheostat is used, open the line switch or circuit-breaker. Never force the starter handle to the "off" position, but allow it to return automatically.

If the motor is to be shut down for a considerable period, open the line switch or breaker.

Reversing Motor-Generator

The rotating element of the motor generator should revolve in a clockwise direction as observed by viewing the generator end of the set. If this is not the case when the motor is started, then the wiring connections for the motor must be changed.

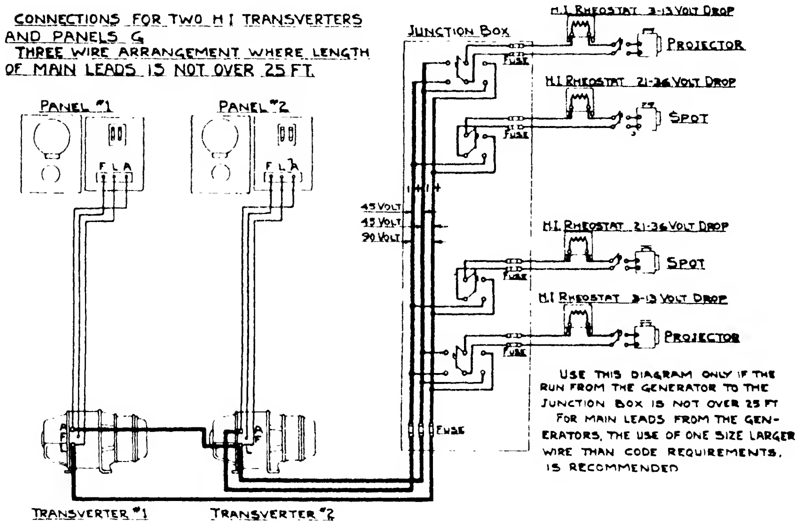
Type CS Polyphase Motor

To Reverse Motor—To reverse a two-phase, four-wire motor, the two leads of one phase should be interchanged. To reverse a two-phase, three-wire motor, the two outside leads should be interchanged. To reverse a three-phase motor, any two leads should be interchanged.

Type AR Single-Phase Motor

To Reverse Motor—The direction of rotation is determined by the position of the brushes and is indicated by a scale on the rocker ring and a pointer on the front bearing bracket. The scale consists of three lines marked RR, N, and RL, respectively. When the rocker ring is turned so that the pointer is opposite RR, the motor will run in a right-hand or clockwise direction (facing the commutator), and when the pointer

is opposite RL, the rotation will be left-hand or counter-clockwise. N, is the neutral point; the armature will not turn if the pointer is opposite this line. To reverse the motor, therefore, loosen the rocker ring until the pointer is opposite the line for the reverse direction of rotation.



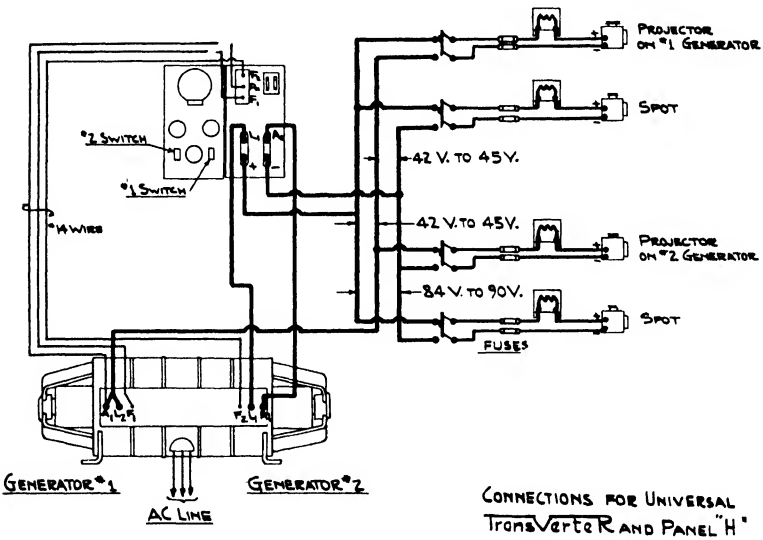
Adjusting the Equipment

After the set is running properly, gradually adjust the generator field rheostat until the potential between the generator terminals, as indicated by the voltmeter, is approximately as follows:

80 volts for	1.6 kw.	20 amp.	generator
80 volts for	2.4 kw.	30 amp.	generator
80 volts for	3.2 kw.	40 amp.	generator
80 volts for	4.8 kw.	60 amp.	generator
80 volts for	6.4 kw.	80 amp.	generator
80 volts for	8 kw.	100 amp.	generator
100 volts for	15 kw.	150 amp.	generator
100 volts for	20 kw.	200 amp.	generator
100 volts for	25 kw.	250 amp.	generator
110 volts for	33 kw.	300 amp.	generator

Two Light—For two-light equipments the short-circuiting switch connected to the ballast in the circuit of either lamp, must always be opened before striking the arc in the lamp.

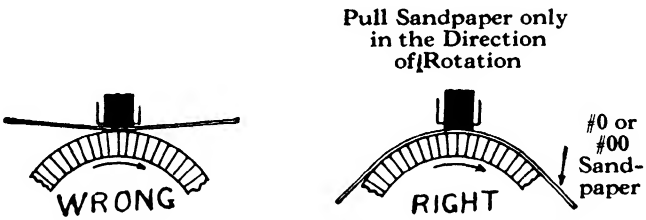
With lamp No. 2 cut off the circuit, open the short-circuiting switch No. 1 move contact arm of ballast rheostat No. 1 to button No. 7, and strike the arc in lamp No. 1. After the carbons have been separated, close the short-circuiting control switch No. 1. and then readjust the carbons until the potential



across the arc is in line with the table as indicated by a reliable voltmeter, the terminals of which are connected directly to the terminals of lamp No. 1. If, under these conditions, the current through lamp No. 1, as indicated by the ammeter, is less than required or less than the full-load rating of the generator, then the contact arm of ballast rheostat No. 1, should be shifted to button 6, or button 5, and so, until the

proper current does flow, when the arc potential is at proper value. This button should be marked for future use.

With lamp No. 1 cut off the circuit, open the short-circuiting switch No. 2, move contact arm of ballast rheostat No. 2 to button No. 7 and strike the arc in Lamp No. 2. After the carbons have been separated, close short circuiting switch No. 2 and then readjust the carbons until the potential across the arc is in line with table as indicated by a reliable voltmeter, the terminals of which are connected directly to the carbons in lamp No. 2. If, under these conditions, the current through lamp No. 2, as indicated by the ammeter, is less than required or less than the full load rating of the generator, then the contact arm of ballast rheostat No. 2, should be shifted to button 6, or button 5, and so on, until the proper current does flow, when the arc potential is at proper value. This button should also be marked for future use.



How To Hold Sandpaper When Seating Brushes

Care of Motor-Generator

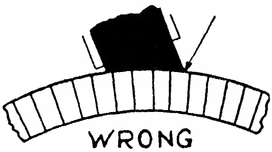
Type SK Generator and Motor—The commutator must be kept clean and the brushes properly adjusted and fitted to the commutator. Wipe the commutator at frequent intervals, depending on the character of the service, with a piece of clean canvas cloth free from lint. Apply lubricant sparingly; a piece of paraffin rubbed lightly across the commutator surface will furnish sufficient lubrication. No other attention is required by the commutator which is taking on a polish and shows no sign of wear. A rough, raw, copper-colored surface should be smoothed with a piece of sandpaper or fine sandstone ground

to fit. In any case the final smoothing should be with fine (No. 00) sandpaper. When using the paper or stone lift the brushes and do not replace them until all grit is removed. Never use emery cloth or emery paper on the commutator.

Brushes—The brushes are set in the neutral position at the factory and the bracket to which they are attached is doweled in position. This adjustment should not be altered as it is correct for either direction of rotation.

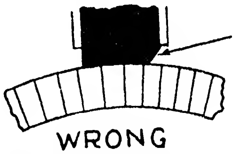
New brushes should be of the same make and grade as those shipped with the machine. Brushes should have only sufficient clearance in the box to slide easily.

Brush Tip Breaks and Burns



Brush Stud Too Close to Commutator

Brush Tip Breaks and Burns



Brush Holder Too Far from Commutator Contact Area Reduced By Breaking of Tips

Type AR Single-Phase Motor

Renewing Brushes—To remove brushes from the holder, turn the rocker ring so that the brushes are brought between the arms of the bearing bracket. Remove the screws of the clips that hold the brushes in place. After inserting new brushes, turn the rocker ring so that the pointer is opposite the line for the proper direction of rotation.

The front bracket of the motor should not be removed unless unavoidable. If the bracket is removed, when replacing make sure that the steel pin in the brush-raising ring enters the corresponding slot in the brush-holder casting. Failure to observe this may result in poor operation.

General Pointers

Generator Excitation—When a generator is started, it may

fail to build up its voltage properly. This may occur even though the generator operated perfectly during the preceding run. This may be due to one or more of the following causes:

(a) Slow speed.

(b) Open shunt-field circuit, caused by faulty connections or defective field coil or field rheostat.

(c) Open armature or commutating-field circuit.

(d) Incorrect setting of brushes.

(e) Reversed series or shunt coils.

(f) Poor brush contact due to dirty commutator or brushes sticking in holders.

(g) Loss of residual magnetism.

Examine all connections, try a temporarily increased pressure on the brushes; look for a broken or burned out resistor coil in the rheostat. An open circuit in the field winding may sometimes be traced with the aid of a magneto and bell; but this is not an infallible test as some magnetos will not ring through a circuit of such high resistance as some field windings have, even though the winding be intact. If no open circuit is found in the rheostat or in the field winding, the trouble is probably in the armature. But if it be found that nothing is wrong with the connections or the winding it may be necessary to excite the field from another generator or some other outside source. Calling the generator that we desire to excite, No. 1, and the other machine from which the current is to be drawn, No. 2, the following procedure should be followed:

Open all switches and remove all brushes from generator No. 1; connect the positive brushholder of generator No. 1 with the positive brushholder of generator No. 2; also connect the negative holders of the machines together (it is desirable to complete the circuit through a switch protected by a fuse of about 5 amperes). Close the switch. If the shunt winding of generator No. 1 is all right, its field will show considerable magnetism. If possible, reduce the voltage of generator No. 2 before opening the exciting circuit; then break the connections. If this cannot be done, set the field rheostat contact arm of generator No. 1 on button marked "IN," then open the switch very slowly and gradually lengthen the arc, which will be formed, until it breaks.

A very simple means for getting a compound-wound ma-

chine to pick up is to short-circuit it through a fuse having approximately the current capacity of the generator. If sufficient current to melt this fuse is not generated, it is evident that there is something wrong with the armature, either a short circuit or an open circuit. If, however, the fuse has blown, make one more attempt to get the machine to excite itself. If it does not pick up, it is evident that something is wrong with the shunt winding or connections.

If a new machine refuses to build up voltage and the connections apparently are correct, reverse the field connections, *i.e.*, interchange the field wires which are connected to the positive and negative terminals of the generator. If this interchange of connections does no good, re-establish the original connections and locate the fault as previously advised.

Brushes—All brush faces resting on the commutator should be fitted to the commutator so that they make good contact over the entire area. This can be most easily accomplished after brushholders have been adjusted and the brushes inserted. Lift one set of brushes so that they will not be forced against the commutator. Place a piece of sandpaper against the commutator with the sanded side towards the brushes. Replace one brush in its holder and allow the spring to force it against the sandpaper. Draw the sandpaper in the direction of rotation under the brush, releasing the pressure as the paper is drawn back being careful to keep the ends of the paper as close to the commutator surface as possible and thus avoid rounding the ends of the brush. After the first brush is properly ground, it should be lifted sufficiently to prevent it being forced against the commutator, after which the remaining brushes of the set may be similarly ground one at a time.

By this means a satisfactory contact is quickly secured, each set of brushes being similarly treated in turn. If the brushes are copper plated, their edges should be slightly beveled, so that the copper does not come in contact with the commutator.

Make frequent inspection to see that:

(a) Brushes are not sticking in holders.

(b) Pig-tail shunts are properly attached to brushes and holder.

(c) Tension is readjusted as the brush wears.

(d) Copper plating is cut back so it does not make contact with commutator.

(e) Worn-out brushes are replaced before they reach their wearing limit and break contact with the commutator.

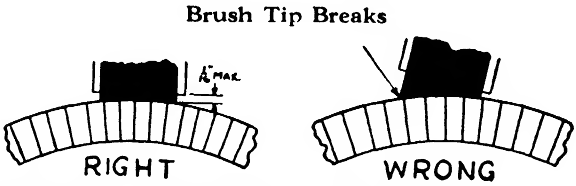
(f) Any free copper picked up by the face of the brushes is removed.

Commutator—The commutator is perhaps the most important part of the machine in that it is most sensitive to abuse. Under normal conditions, it should require little attention beyond frequent inspection. The surface should always be kept smooth, and if, through extreme carelessness, neglect or accident, it becomes badly roughened, the armature should be removed and the commutator turned down in an engine lathe.

Sparking at the brushes may be due to any one of the following causes:

(a) The machine may be overloaded.

(b) The brushes may not be set exactly on the neutral po-



Brush Holder—1/16 Inch Max. from Commutator

Brush Stud Too Far fom Commutator

sition. If so, the neutral should be determined by running the machine in both directions of rotation and obtaining the same voltage at full load current in both directions.

(c) The brushes may be welded in the holders or have reached their limit of wear.

(d) The brushes may not be fitted to the surface of the commutator.

(e) The brushes may not bear on the commutator with sufficient pressure.

(f) The brushes may be burned on the ends.

(g) The commutator may be rough. If so, it should be smoothed.

(h) A commutator bar may be loose or may project above the others.

(i) The commutator may be dirty, oily or worn out.

(j) The carbon brushes may be of an unsuitable grade.

(k) The brushes may not be equally spaced around the periphery of the commutator.

(l) Some brushes may have extra pressure and may be taking more than their share of the current.

(m) The contact between some brush pig-tails and brush-holders may be poor, forcing the other brushes to carry too much current.

(n) High mica.

(o) Vibration or chattering of the brushes.

These are the more common causes, but sparking may be due to an open circuit or loose connection in the armature. This trouble is indicated by a bright spark which appears to pass completely around the commutator, and may be recognized by the scarring of the commutator at the point of open circuit. If a lead from the armature winding to the commutator becomes loose or broken it will draw a bright spark as the break passes the brush position. This trouble can be readily located, because the insulation on each side of the disconnected bar will be more or less pitted.

The commutator should run smoothly and true, and have a dark glossy surface.

Heating—Many persons not familiar with permissible operating temperatures of electrical apparatus become unduly alarmed when they find that the various parts of a motor-generator feel very hot to the fingers. However, it is extremely inadvisable to permit the equipment to operate above certain temperatures because the insulation will become charred and the current will break through burning out the windings. The only safe and certain way to determine temperatures is to use centigrade thermometers, the bulbs of which can be applied directly against the parts, which are suspected of being too hot, by means of putty over and around the bulb.

The standardization rules of the American Institute of Electrical Engineers specify a maximum actual temperature of 90°C. (194°F.) as the limit of safe temperature for such motor-generator equipments. In other words a temperature rise of 50°C. (90°F.) above a maximum permissible room temperature of 40°C. (104°F.). Obviously a temperature of 104° Fahrenheit would feel hot to the hand having a blood temperature of only about 98° Fahrenheit.

It is not uncommon for projection room temperatures especially in hot weather to reach a value of 35°C. (95°F.) to 40°C. (104°F.) but even if the room temperature was only 22°C. (72°F.) and the motor-generator operates at a temperature rise of 50°C. (90°F.) the actual temperature of the motor-generator would be 72°C. (162°F.) which would also feel hot to the hand or fingers. Therefore unless the room temperature exceeds 40°C. (104°F.) and unless the actual temperature of the hottest part of the motor-generator as indicated by a reliable thermometer exceeds 90°C. (194°F.) the equipment will not be damaged.

To reduce centigrade temperature to Fahrenheit multiply the degrees Centigrade by 1.8 and add 32. For example projection room temperature of 40°C. corresponds to what temperature Fah. $40 \times 1.8 = 72$; $72 + 32 = 104°$ Fahrenheit.

Heating of Field Coils—Heating of field coils may result from any of the following causes:

(a) Too low speed.

(b) Too high voltage.

(c) Too great forward or backward lead of brushes.

(d) Partial short-circuit of one coil.

(e) Overload.

Heating of Armature—Heating of armature may result from any of the following causes:

(a) Too great load.

(b) A partial short-circuit of two coils heating the two particular coils affected.

(c) Short-circuits or grounds in armature windings or commutator.

(d) Bad commutation with consequent large circulating currents in armature coils undergoing commutation.

Heating of Commutator may result from any of the following causes:

(a) Overload.

(b) Sparking.

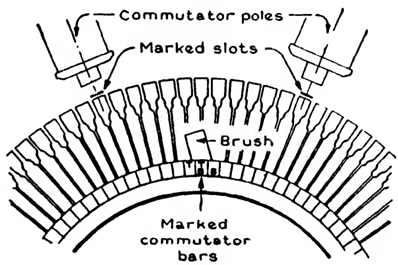
(c) Too high brush pressure.

Bucking is the very expressive term descriptive of the arcing between adjacent brush arms. In general, bucking is caused by excessive voltage between commutator bars, or by abnormally low surface resistance on the commutator between brushholders of opposite polarity. Any condition tending to produce poor commutation increases the danger of bucking. Among other causes are the following:

(a) Rough or dirty commutator.

(b) A drop of water on the commutator from the roof, leaky steam pipes or other source.

(c) Short-circuits on the line producing excessive overloads.



Factory marks on armature slots and commutator bars help to locate neutral.

THE ROTH ACTODECTOR

The Roth Actodector is the trade name given a line of motor generator sets particularly designed for furnishing current for projection room arcs.

The sets are built in standard sizes from the 25-50 ampere machines for multiple operation of two low intensity arcs up to the 225-450 ampere machines for use in the largest theaters with high intensity arcs. All machines are given a continuous

and double rating. The continuous rating is the load the generator will carry continuously with a temperature rise on the windings not to exceed 40°C.

The maximum or double rating is the number of amperes the generator will deliver for a period of 15 minutes without any serious heating. This rating is given because of the widely varying load and short time overloads to which all motion picture generators are subjected.

ROTH STANDARD SIZES

Double Rating	Continuous	15 Minutes
25— 50 Amp.	30 Amp.	50 Amp.
35— 70 "	50 "	70 "
50—100 "	75 "	100 "
75—100 "	100 "	150 "
100—200 "	150 "	200 "
110—220 "	150 "	220 "
140—280 "	200 "	280 "
180—360 "	250 "	360 "
225—450 "	300 "	450 "

All Roth Actodectors are compound wound for multiple operation of projection room arcs. A suitable ballast resistance must be placed in series with each arc. The generators are designed by scientific proportioning of design to operate at an unusually low voltage so that a comparatively high efficiency is obtained because of little loss in ballast resistances. Sizes up to 100—200 ampere are 70 volt machines and larger sizes are 85 volt machines.

Special 100 volt Actodectors are also built for certain requirements. Sets with 60 cycle motors operate at 1750 RPM although some special machines are built to order with a speed of 1150 RPM. Sets with 50 or 25 cycle motors have a rated speed of 1450 RPM. The three smaller sizes (25—50, 35—70, 50—100) are furnished in the two bearing type. Larger sizes are four bearing, two unit types with motor and generator direct connected by a flexible coupling and mounted on the same bed plate.

Generators have phosphor bronze ring oiled bearings, steel frames, laminated poles, and long face commutators with ample brush surface so the amperes per square inch of brush surface is low. The following table gives data on wiring of generator:

Generator Rating	Size Wire	Size Fuse	Size Switch	Size Conduit
25— 50	4	60	100	1¼
35— 70	1	90	100	1½
50—100	00	120	200	2
75—150	0000	200	200	2
100—200	300 cm	250	400	2½
110—220	300	275	400	2½
140—280	500	350	400	3
180—360	700	450	600	3½
225—450	800	550	600	3½

Each generator is provided with a control frame on which is mounted a voltmeter, ammeter and generator field rheostat.

Driving motors are of the squirrel cage type, ring oiled bearings, laminated electric sheet steel stators, rotors with bars welded in the end rings. The following table gives motor installation data:

BRANCH WIRING TO MOTOR

		Supply current 220 v 3 phase				Supply current 440 v 3 phase			
Generator	Motor H. P.	Size Wire	Conduit Size	Running Fuse	Size Switch	Size Wire	Conduit Size	Running Fuse	Motor Switch
25— 50	3	14	½	15	30	14	½	10	30
35— 70	5	12	½	20	30	14	½	10	30
50—100	7½	10	¾	30	30	14	½	15	30
75—150	10	8	¾	40	60	12	½	20	30
100—200	15	6	1¼	50	60	10	¾	25	30
110—220	20	4	1¼	70	100	8	¾	35	60
140—280	25	3	1¼	80	100	6	1¼	40	60
180—360	30	1	1½	100	100	6	1¼	50	60
225—450	40	00	2	150	200	4	1¼	65	100

When the motor generator installation consists of two sets the following data may be used for the wiring of the mains:

		220 V 3 phase supply		440 V 3 phase supply	
Generator	Motor H. P.	Wire Size	Conduit Size	Wire Size	Conduit Size
2—25—50	2—3	14	½	14	½
2—35—70	2—5	10	¾	14	½
2—50—100	2—7½	6	1¼	12	½
2—75—100	2—10	6	1¼	10	¾
2—100—200	2—15	3	1¼	6	1¼
2—110—220	2—20	0	2	4	1¼
2—140—280	2—25	00	2	4	1¼
2—180—360	2—30	000	2	3	1¼
2—225—450	2—40	0000	2½	0	2

Ballast resistances which must be used with all Roth Actodectors should be mounted at least 5 feet from the floor on a shelf of slate or similar material. Connections to the ballasts should be made with asbestos covered wire. The resistances are either single or double types—the single type has but a single resistance in a screen or perforated metal housing and takes care of one arc. The double type has two independent resistances in a housing and takes care of two arcs. All ballast resistances are provided with taps for adjusting the current to meet arc requirements.

Multiple Type Transverter—Operation

Close the switch, and if a hand starter is provided, bring it to the "start," allow the unit time to accelerate and then to the "run" position. If a single phase unit, it is particularly essential to permit the armature time to come well up to its running speed before the handle is thrown over to the side marked "run."

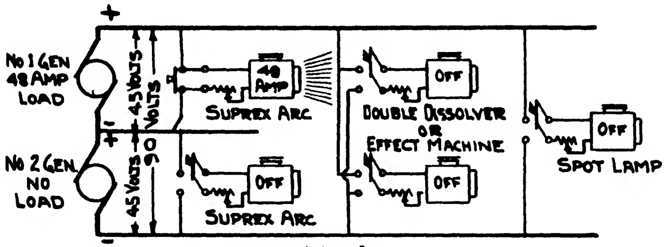
The proper direction of rotation is shown by an arrow on the generator. This direction is counter clockwise when viewing the generator from the commutator end. If run in the wrong direction, it will not generate.

To reverse the direction of rotation in the case of a three phase unit, interchange two of the three motor leads. In the case of the two phase motor, reverse the wires of either phase. In the case of a single phase unit, the wires are brought out so as to assure correct rotation, care must be taken, however, to have each wire going to the proper point on the starter.

If the direction of rotation is correct, the generator will

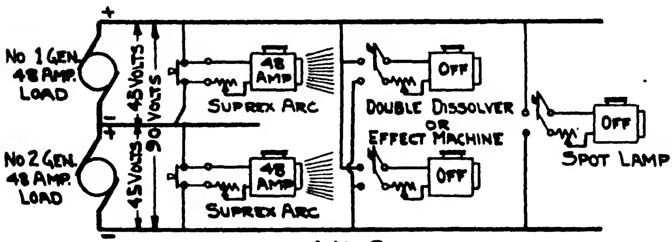
build up to the operating voltage which is dependent on its size, as the larger arcs and particularly the high intensity need higher voltage than the smaller ones.

At this point, if the machine is of the Oil Bearing type, it is well to inspect the bearings to see that the rings are all freely revolving and carrying the oil in the proper manner. A slight



NO. 1

FIRST 34 VOLT SUPREX ARC PROJECTOR BURNING ON ITS 45 VOLT SUPPLY.



NO. 2

CHANGE-OVER TO SECOND SUPREX ARC PROJECTOR, BOTH ARCS BURNING FROM THEIR RESPECTIVE 45 VOLT SUPPLY.

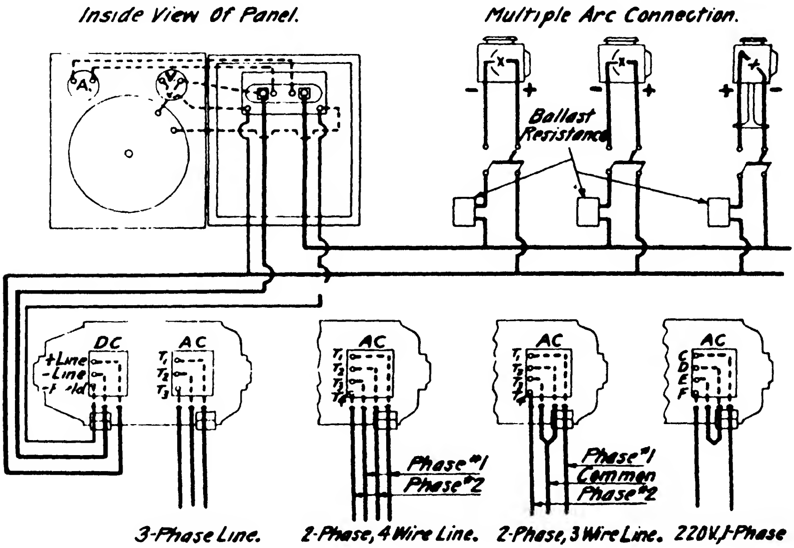
lengthwise floating of the shaft indicates that the foundation has been correctly placed.

Strike the arc. In the smaller values of current, it is general practice to leave the ballast at its normal setting. On the larger arcs a separate shorting switch is often used, which at the start, is left open to increase the ballast resistance so as to keep the amperes somewhat near normal when striking and while the arc is short and the arc voltage low. After a few sec-

onds this switch is closed because the arc can now be drawn to normal length.

A short time before the first film is run off, the second arc is started in the same manner and as soon as the second film is in operation the first arc is cut off. It is during this period that the unit is called upon to carry the double load.

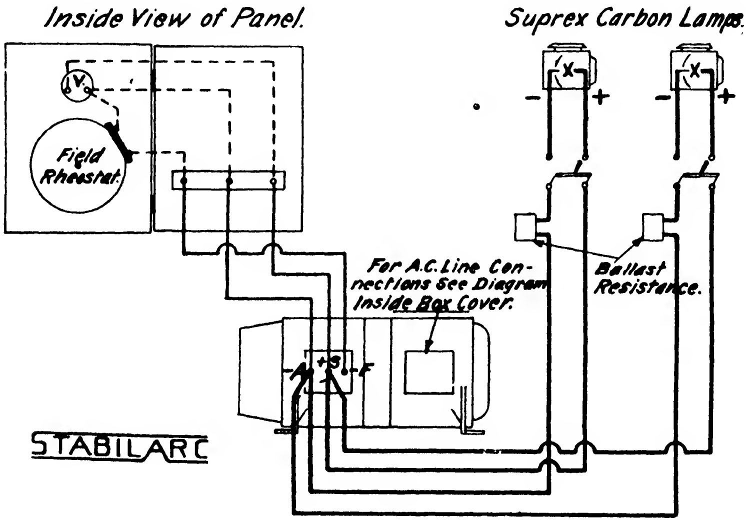
When operating arcs off a multiple generator there is a definite relationship between arc length and arc amperes on the one hand and rheostat capacity and generator voltage on the other.



In the multiple type generator of the small sizes the voltage will climb somewhat if the field regulator is set to deliver the desired voltage before the arc is struck so that the voltage will be high after the arc is burning. The open circuit voltage may be disregarded and the regulator adjusted to the proper point after the arc is struck.

In order to parallel two multiple generators it is necessary to have a connection between them, called an equalizer. The reason for this is easy to see.

In order to get constant potential performance compounding is required and this compounding differs on various sizes and designs of machines, in fact it may vary somewhat on two machines of identically the same design and even changes in a given machine with change in operating voltage or brush position.



Supposing two generators are set for parallel operation and are balanced as to their compounding, having the proper equalizer connection. If one of these generators is started and operated over a period of time until it warms to a fair degree before the second one is started, this second generator will be thrown on with its voltage adjusted to match that of the first unit. As the second machine warms its voltage will drop and it will lose part of its load which the first unit will take. The field of number two must be strengthened by hand regulation to make up for this loss.

Usually two generators of the same design will parallel nicely if they are equalized but will need some attention at the field regulators so as to properly divide the load.

If they are of different design it may be necessary to have a competent person bring the two units to the same performance characteristics. This is accomplished by the insertion of the proper shunting resistance in series and in shunt with the series field so that with the same shape of performance curve the drop between the equalizer and main bus connections will be the same on the two machines when they are equally loaded.

Satisfactory performance in parallel presupposes an equalizer connection of extremely low resistance and the use of a three pole switch for each generator with the equalizer connection through one of the three blades is satisfactory if the lines to the generators are short and heavy and the switches in good condition. In no case should the equalizer circuit be fused.

It would be much better from a practical standpoint to eliminate the switch connection entirely and connect the equalizers directly by a heavy conductor running from the "E" lead of one generator to the "E" lead of the other.

Operation—Series Type Transverter

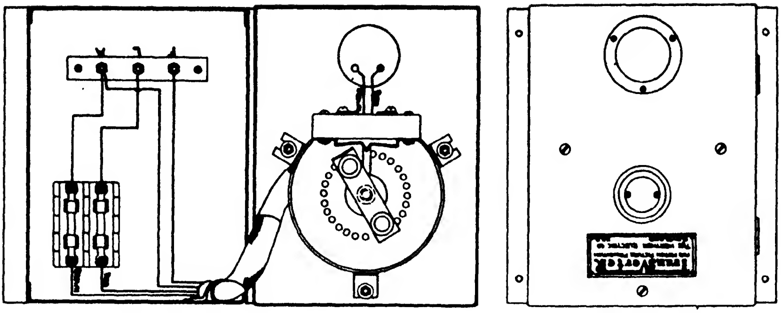
Close the service switch. If a hand starter is provided, bring it to the starting position, giving the unit time to accelerate and then to the running position. If a single phase unit, it is particularly essential to permit the armature time to come well up to its running speed before the handle is thrown over to the side marked "Run."

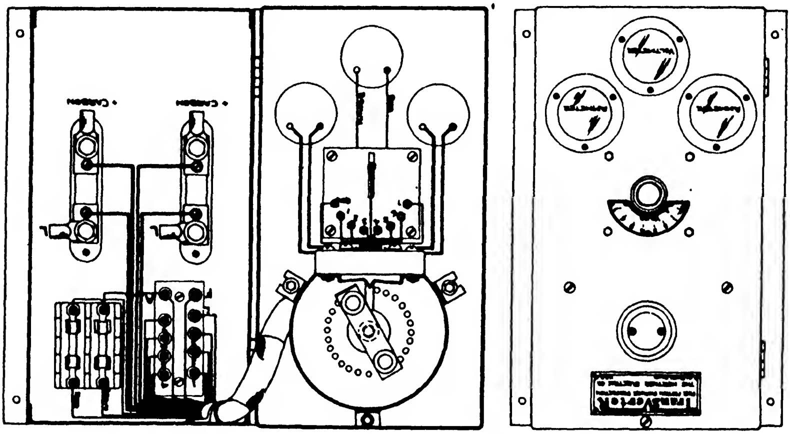
If the direction of rotation is not correct, reverse as already explained in connection with the multiple unit.

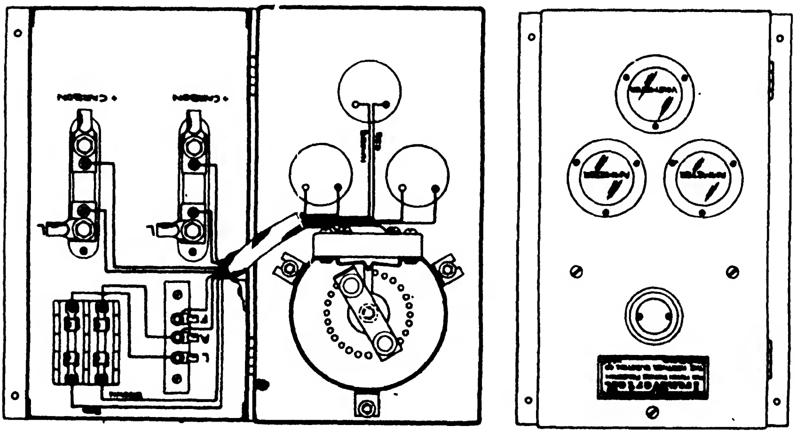
If the direction of rotation is correct, the generator will build up as soon as the short circuiting switch of either arc is opened, provided the carbons are apart.

If the carbons are now brought together, the arc will be struck and can be opened to its proper length. The field regulator can then be set for the required current value.

When the film of projector No. 1 is about to run out, touch the carbons in projector No. 2 and open the shorting switch. The carbons will, at once, begin to glow and the arc can be opened without further delay. As soon as No. 2 is in opera-

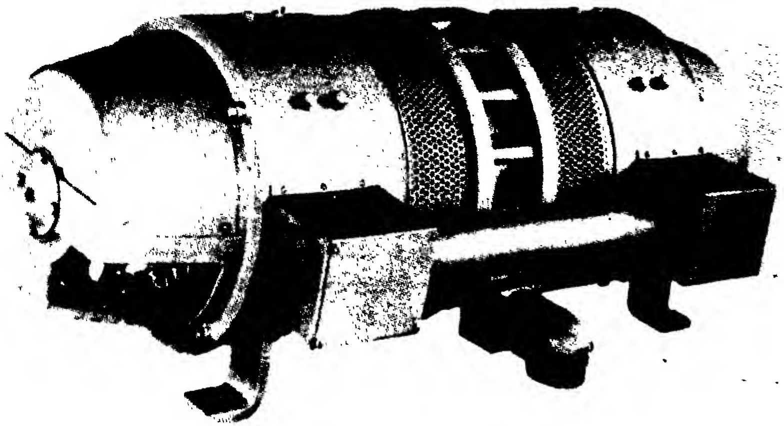






tion the shorting switch of No. 1 can be closed and the carbons brought together. Some projectionists reverse this process, closing the carbons first and the switch afterwards with the idea of a somewhat smoother changeover.

In a general way, there are only three parts of the unit subject to wear; the commutator, brushes and bearings. The commutator, if properly cared for, will last many years. It should take on a polish which needs only an occasional wiping with a canvas, having previously had a very slight application of vaseline. Use only the brushes recommended by the factory.

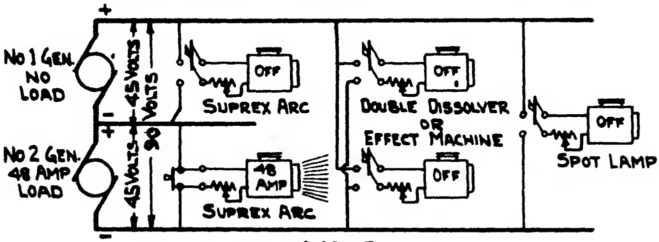


100 Ampere, 42-84 volt Universal TransVerteR and Control Pane

Sometimes a commutator will get rough. In this case it can be cleaned up with a commutator stone if bad or with fine sand paper if very slight. If the commutator is badly out of round the use of the commutator stone will not give permanent results because the stone will follow the surface, for while any abrupt irregularity is removed, the eccentricity remains. In this event two courses are open. One plan is to take the armature out of the machine and turn the commutator in a lathe. The turning operation is a trifling one but the time and expense of removing and returning it are serious, especially if a large unit. A less expensive plan and one that produces excellent results is to raise the brushes and turn the commutator in place, using

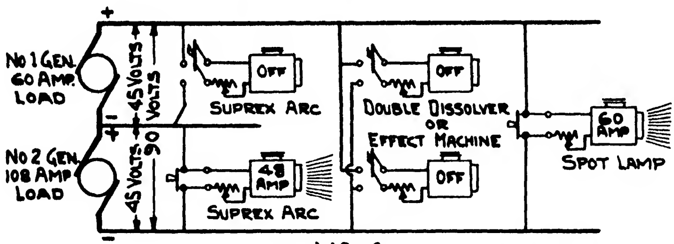
a rather sharp round nose diamond tool at full running speed. This is followed by a light stoning and will produce a surface that is almost absolutely true.

The brushes have been adjusted to their proper position at the factory and this location is plainly marked. Shifting them will over or under compound a multiple unit and will cause a series machine to either go to a higher or lower maximum as well as upset the constancy of its performance.



NO. 3

SECOND 34 VOLT SUPREX ARC PROJECTOR BURNING ON ITS 45 VOLT SUPPLY.

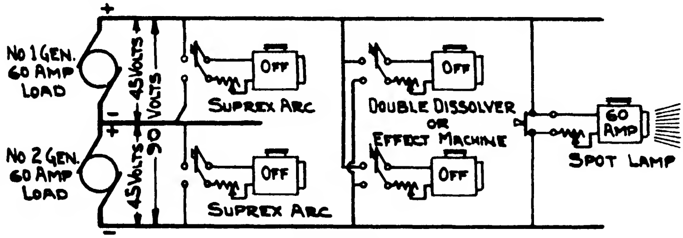


NO. 4

CHANGE-OVER TO 55 VOLT SPOT ARC. SUPREX ARC BURNING ON 45 VOLT SUPPLY, SPOT ARC BURNING ON 90 VOLT SUPPLY.

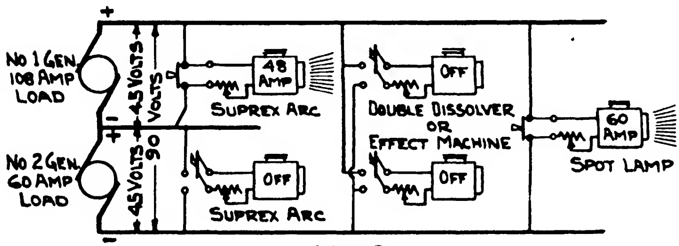
To fit brushes they should be set into position on the commutator and a piece of medium sand paper drawn back and forth under them and held close against the commutator surface. As soon as they show a contact completely across their face, it is well to finish with fine sand paper, drawing it *only in the direction of rotation.* The brushes should never run on the micanite. The micanite is undercut at the factory and the commutator should run for a long time without reaching the point where most undercutting need be done. If, however, the commutator is turned the probabilities are that more micanite

must be removed. This should be done to a depth of from 1/32 to 3/64 inch.



NO. 5

55 VOLT SPOT. ARC BURNING ON 90 VOLT SUPPLY.



NO. 6

CHANGE-OVER TO 34 VOLT SUPREX ARC. PROJECTOR SUPREX ARC BURNING ON 45 VOLT SUPPLY, SPOT BURNING ON 90 VOLT SUPPLY.

Fort Wayne AC to DC Compensarcs

The AC to the DC Compensarcs is what is commonly known as a motor generator set, that is, two machines, a generator and a motor coupled together and mounted on a common base.

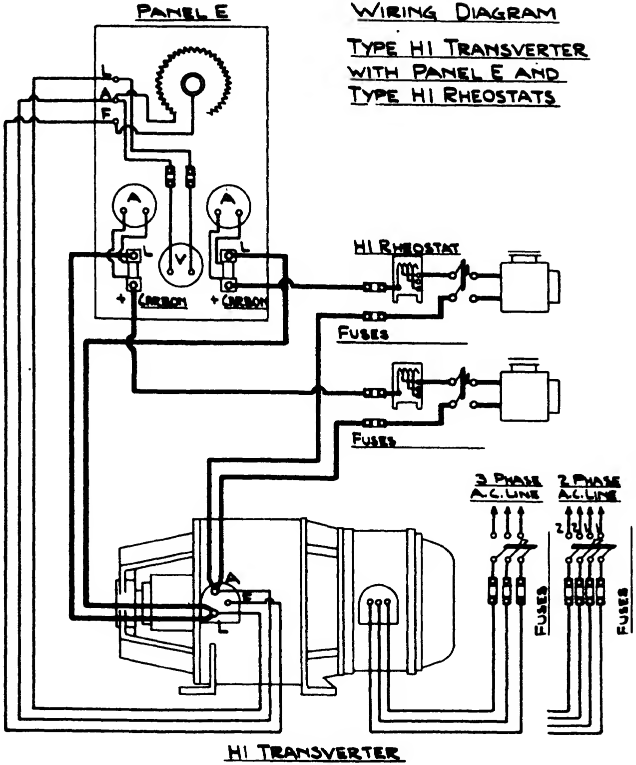
It should be understood that these compensarcs are special machines for use only on picture projection arcs and cannot be used for ordinary constant voltage purposes.

The complete equipment consists of the AC to DC compensarc proper, two short-circuiting switches, one for each picture machine, and the panel on which is mounted the instrument and field control rheostat. All single-phase outfits are equipped with proper starter; for the larger multiphase outfits a starting compensator is furnished.

The AC to DC Compensarc should be installed in a clean, dry, well, ventilated location, and, if possible, near to the lamps

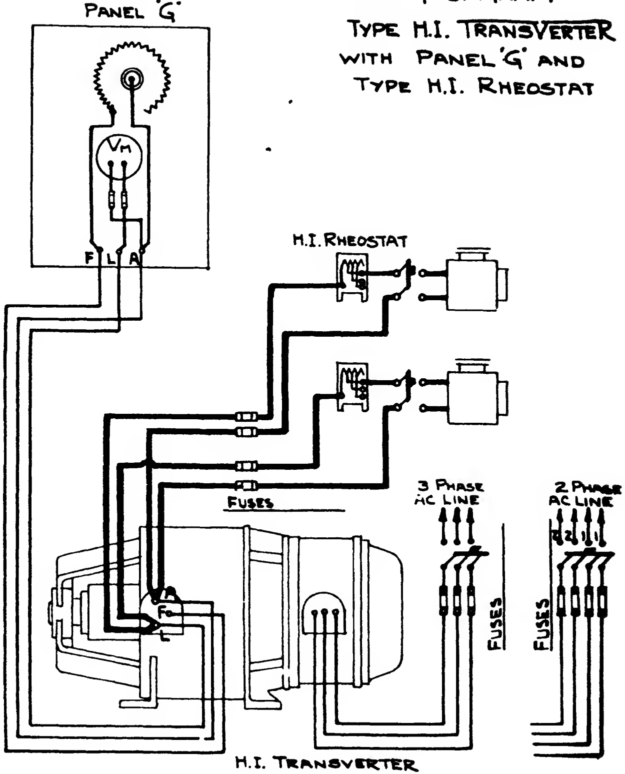
Wiring Diagram

Type HI Transverter
with Panel E and
Type HI Rheostats



Wiring Diagram

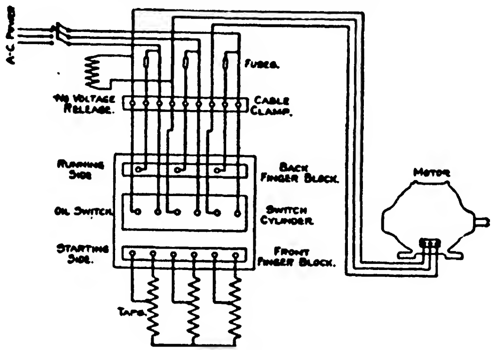
Type H.I. Transverter
with Panel 'G' and
Type H.I. Rheostat



which it is to operate. Oftentimes a small room adjoining the projection room is provided for the Compensarc; but in some cases where such arrangements cannot be made the machine is installed in the basement of the theater. Inaccessible locations should be avoided, as such locations will result in the machines being neglected, allowed to become dirty and perhaps damaged.

It is not necessary to provide foundations for those compensarcs, but the floor on which they are placed should be firm and free from vibration.

A.C. TO D.C. COMPENSARCS



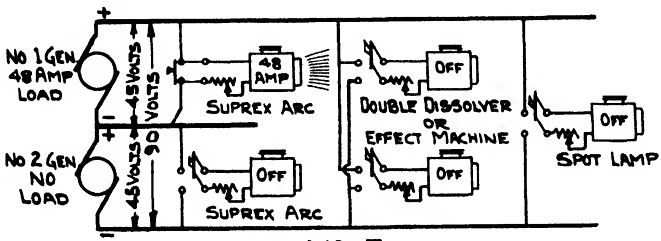
Connections of Motor End of A.C. to D.C. Compensarc Three-Phase

The machines are clamped to a pair of wooden skids, which form a foundation for the boxing. The machine should if possible be left attached to these skids until it has been conveyed to the location which it is finally to occupy. It is preferable that all wiring should be done before the boxing is removed from the machine, as the boxing will be effective in keeping the machine clean.

The AC to DC Compensarc should be run only on circuits where the variation of either frequency or voltage from normal does not exceed five per cent. Where both frequency and voltage vary, the sum of the variation must not exceed eight per cent.

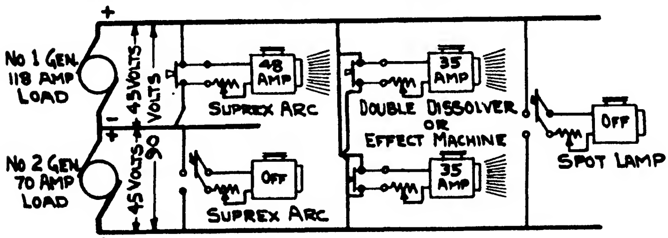
If for any reason the generator or motor must be taken

from the base in order to install the compensarc, great care should be exercised that the machines are properly lined to give a uniform air gap when the compensarc is reassembled. If this is not true, trouble will occur due to the set being out of line. Dowell pins are provided on the generator end. To remove these hold the squared head of the pin with a wrench and tighten up the nut which will pull out the pin. Be careful that any liners found under the feet are carefully replaced in their proper place. Should the coupling be taken apart, it must be assembled carefully, making sure that the halves fit properly.



NO. 7

FIRST 34 VOLT SUPREX PROJECTOR AGAIN BURNING ON ITS 45 VOLT SUPPLY.

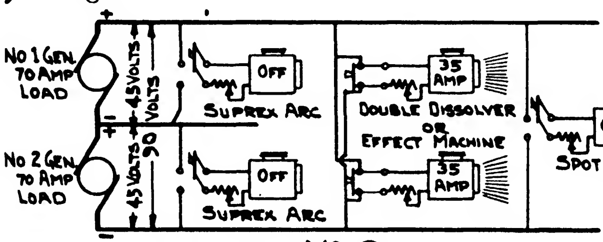


NO. 8

CHANGE-OVER TO 55 VOLT ARCS ON EFFECT MACHINE. SUPREX ARC BURNING ON 45 VOLT SUPPLY, DISSOLVER ARCS BURNING ON 90 VOLT SUPPLY.

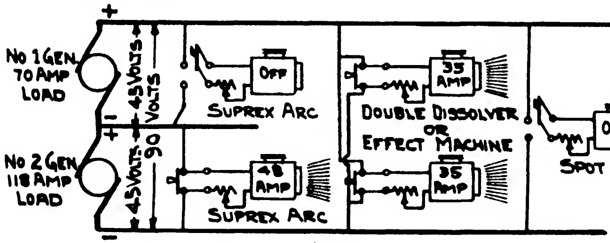
The wiring should be of sufficient size so that the line drop from the machine to the lamp will not exceed one volt, or two per cent of the voltage when the machine is delivering full-load current to the lamp. If too small a wire is used the lamp will be robbed of some of its voltage and give poor light. The lamp side of these machines does not require fuses, as the generators are so constructed that they will protect themselves against overload current when the arcs are short circuited.

Before starting the set see that it is perfectly clean and that the brushes move freely in their holders and make good contact with the commutator. Be sure that the oil wells are clean and filled. These machines have overflow gauges with hinged caps. The oil wells should be filled through the overflow gauges rather than through the hinged covers in the bearings. This method will prevent waste and annoyance from overflowing of the oil reservoirs. Pour in enough oil to show in the gauges, the thin oil furnished for the moving picture machine, sewing machine oil and similar light oils are not heavy enough.



NO. 9

55 VOLT EFFECT MACHINE ARCS BURNING ON 90 VOLT SUPPLY.



NO. 10

CHANGE-OVER TO 34 VOLT SUPREX ARC PROJECTOR. DISSOLVER ARCS BURNING ON 90 VOLT SUPPLY, SUPREX ARC BURNING ON 45 VOLT SUPPLY.

See that the armature turns freely in the bearings and that the machine is level.

Make sure that all the connections are tight and correspond with the diagram of connections for the outfit supplied.

When starting up see that the armature starts to rotate in the direction marked on the coupling. The direction of rotation of two-phase motors can be reversed by interchanging two line leads of the same phase. In the case of single and

three-phase motors it is only necessary to interchange any two line leads of the motor. Immediately after starting, see that the oil rings revolve and carry the oil up to the shaft. Always keep the oil at the proper level in the well, that is, nearly to the lip of the overflow gauge.

Starting the Compensarc

In starting up the AC to DC Compensarc, have the switches at the lamps open. If a single-phase outfit, close the main switch and move the starting arm on the starting box from the "off" position to the split segment which will introduce the necessary starting coils to cause the armature to start to rotate. When the armature has attained nearly full speed, the starting arm should be moved quickly over the last segment where it is held by a latch controlled by a relay magnet. If the voltage fails, the relay magnet will release the latch, allowing the starting arm to automatically return to the "off" position stopping the motor.

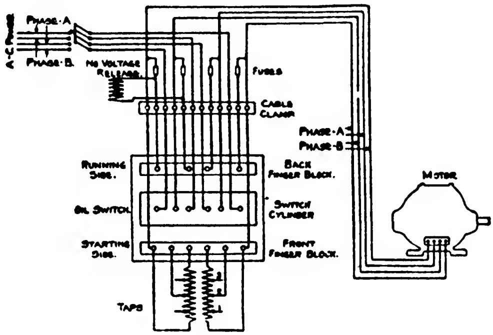
The arm of the starting box should never be left in starting position longer than one minute, usually much less time will suffice. When the power companies do not require the use of starting compensators in connection with the two and three-phase outfits they should be equipped with double-throw starting switches which have only one side fused.

When starting up, the switch should be closed to the unfused side. When the speed of the armature is up to normal the switch should be quickly changed to the running side (fused side).

To start up an AC to DC Compensarc where a starting compensator is used, see that compensator arm is in "off" position and close the main switch. The compensator should be thrown into the starting position with a quick, firm thrust and held there until the machine comes up to speed (about 20 to 30 seconds), and then with one quick firm movement the arm should be pulled over into the running position, where it is held by a lever engaging with the low-voltage release mechanism.

Never, in any case, should the motor be started by "touching," that is, by throwing the starting arm into the starting position and quickly pulling it out a number of times. Such a plan of "touching" does not make the rush of current at starting less, but, on the contrary, it produces a number of successive rushes in place of the one which it has been attempted to avoid, and, what is often a more serious matter, it causes the contact fingers to be so badly burned that it is necessary to replace them. To stop the machine open the main switch. The compensator arm should automatically return to the "off"

A.C. TO D.C. COMPENSARCS



Connection of Motor End A.C. to D.C. Compensarc Two-Phase

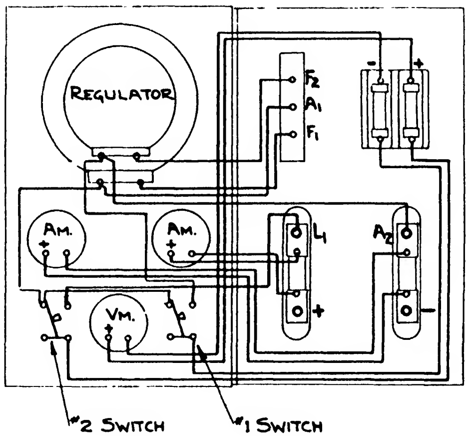
position on the opening of the main switch; if it does not, throw it over to the "off" position by hand.

Starting First Lamp

When the speed of the machine is up to normal and the starting box or switch is in running position and the rheostat handle set as marked by the white arrow, short-circuit the one lamp by means of its short-circuiting switch. Then close the lamp switch and bring the carbons together so that they barely touch; then separate them about 1/16 of an inch, gradually increasing the separation as carbons heat up until the proper length of arc is reached. The DC arc should be from 5/16 to

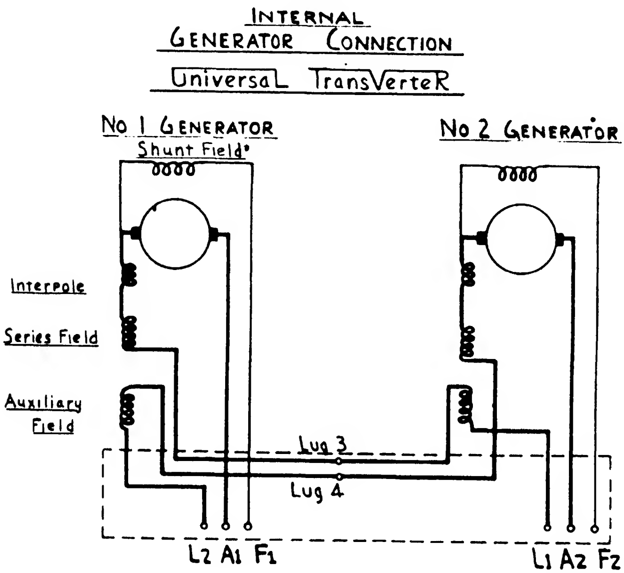
3/8 of an inch long or about twice as long as an AC arc. Adjust the generator field rheostat until the proper amount of current is flowing. If the carbons are held together too long the machine voltage will be automatically reduced to zero, so that the arc will not have sufficient voltage, and will therefore break when the carbons are separated. Should this occur keep the carbons apart about 10 seconds until the machine voltage can automatically build up again, then strike the arc as directed above.

WIRING DIAGRAM
INTERNAL CONNECTIONS
TRANSVERTER PANEL 'H'



The switchboard panel, having instruments mounted on it along with the field rheostat, is very useful, and the proper current can at all times be accurately maintained. As the machine warms up, the handle of the rheostat may have to be moved one or two buttons from the mark to maintain the desired voltage and current. If the circuits are all connected as shown in the diagram, the polarity should be as indicated, the upper carbon being positive. Should the upper carbon be negative and the instrument on the panel board read backward,

the trouble must be corrected. See that all connections are made as indicated on the diagram. The polarity must come correct if the connections are made in accordance with the diagram of connections, and the armature of the set rotates in the direction on the coupling.



Starting the Second Lamp

To start the second lamp, bring the carbons together to close the circuits; close the lamp switch and open the short-circuiting switch. This puts the two lamps in series, the current from the first lamp flowing through the second lamp. The arc at the second lamp is adjusted in the regular manner while both lamps are burning. When ready to change over from one lamp to the other, bring the carbons of the first lamp together and close its short-circuiting switch, continuing the projection on the second lamp.

It has been found in practice that the following scheme gives the most satisfactory results. A minute or two before

the end of a reel of film is reached bring the carbons of the second lamp together, close its line switch and open its short-circuiting switch. The current for the first lamp flowing through the carbons of the second lamp causes the tips of the carbons of the second lamp to heat up to a white heat without actually drawing an arc. Since the tips of the carbons are heated up by this method a normal arc is easily and quickly secured when it is time to change over to the second lamp.

Care must be taken that the two lamps are not both burning any longer than is necessary, as the Compensarc is not intended to carry both lamps continuously. The ammeter on the panel will show the current flowing through the arc when either one or both lamps are burning. The voltage is automatically increased by the machine to compensate for the increased drop due to the second lamp and the current is held practically constant.

It is important that all parts of the machine be kept clean. Oil should not be allowed to collect either on the machine or on the floor about it, and the machine should as far as possible be kept free from dust. When the coils of a machine are allowed to become dirty and oil-soaked, it reduces their insulation strength and eventually causes them to burn out. A small hand bellows will be found convenient for removing the dust from the armature windings.

DC to DC Motor-Generator Set For Projection ARC Control

The DC to DC motor-generator set consists of two machines, a generator and a motor, coupled together and mounted on a common base.

The complete equipment consists of the DC to DC motor-generator set, proper starting box, two short-circuiting switches (one for each picture machine) and the panel on which is mounted the ammeter and field control rheostat.

Initial Starting

Before starting the set see that it is perfectly clean, and that the brushes move freely in their holders and make good contact with the commutator.

Be sure that the oil wells are clean and filled. These machines have overflow gauges with hinged caps. Fill the oil wells through the overflow gauges rather than through the hinged covers in the bearings. This method will prevent waste and annoyance from overfilling of the oil reservoirs.

See that the armature turns freely in the bearings, and that the machine is level.

Make sure that all connections are tight and agree with the diagram of connections for the outfit supplied, so that when starting up the armature will start to rotate in the direction marked on the coupling.

Immediately after starting, see that the oil rings revolve freely and carry the oil up to the shaft. Always keep the oil at the proper level in the well, that is, nearly to the lip of the overflow gauge.

Starting the Motor-Generator

In starting up the DC to DC set have the switches at the lamps open. Close the main line switch and move the lever of the starting box to the first contact point holding it there for two or three seconds to allow the armature to start to rotate. Then move the lever slowly over the remaining contact points until it reaches the running position where it will be held in place by the retaining magnet. If the voltage fails the retaining magnet will release the latch allowing the starting arm to automatically return to the "off" position stopping the motor.

To stop the machine open the main switch. The arm of the starting box should then automatically return to the "off" position. If it does not, throw it over to the "off" position by hand.

Starting First Lamp

When the speed of the machines is up to normal and the arm of the starting box is in running position and the rheostat handle set as marked by the white arrow, short circuit the one lamp by means of its short-circuiting switch. Then close the lamp switch of the other lamp and bring the carbons together so that they barely touch; then separate them about 1/16 of an inch, gradually increasing the separation as carbons heat up until proper length of arc is reached. The DC arc should be from 5/16 to 3/8 of an inch long, or about twice as long as an AC arc. Adjust the generator field rheostat until the proper amount of current is flowing.

If carbons are held together too long, the machine voltage will be automatically reduced to zero, so that the arc will not have sufficient voltage and will, therefore, break when carbons are separated. Should this occur, keep carbons apart about 10 seconds until machine voltage can automatically build up again; then strike the arc as directed above.

The switchboard panel has an ammeter mounted on it along with the field rheostat and is very useful as the proper current can at all times be accurately maintained. As the machine warms up, the handle of the rheostat may have to be moved one or two buttons from the mark to maintain the desired voltage and current.

If the circuits are all connected as shown in the diagram the polarity should be as indicated. The upper carbon must be positive. Should the upper carbon be negative and the instrument on the panel read backward, the trouble must be corrected. See that all connections are made as indicated on the diagram.

The polarity must come correct if the connections are made in accordance with the diagram of connections and the armature of the set rotates in the direction marked on the coupling.

STARTING THE SECOND LAMP

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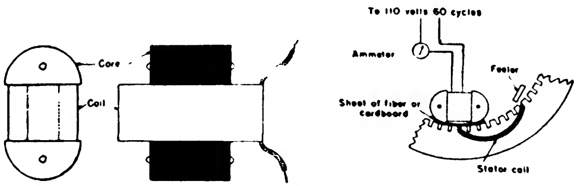


One type of growler that can be made for testing motors for short circuits in the stator winding, and how to use it.

Take care that the two lamps are not both burning any longer than is necessary, as the motor-generator is not intended to carry both lamps continuously. The ammeter on the panel will show the current flowing through the arc when either one or both lamps are burning; the voltage is automatically increased by the machine to compensate for the increased drop due to the second lamp and the current is held practically constant.

MOTORS

THE simplest possible motor is a magnet attracting a bit of iron. The arrangement acts as a motor during the time the iron is moving toward the magnet. Once the iron has reached the magnet, however, no further motion is possible.

Suppose the magnet to be an electro-magnet, and the iron to be suspended in front of it in such a way that it can swing toward or away from the pole, like a pendulum. Then, if a trip switch is arranged to allow the pendulum to open the circuit each time it approaches the magnet and to close it again each time it falls back, a continuous reciprocating motion can be created.

Suppose instead of a piece of iron the magnet is used to attract another conductor carrying current. Then if the trip switch is arranged to reverse the direction of the current through the conductor, the wire will be alternately attracted and repelled.

Reciprocating electric motors of the types described above are sometimes built for use as toys, but for practical purposes a rotary action is more efficient. If the conductor mentioned above, which is attracted or repelled by an electro-magnet, is mounted on the rim of a wheel, and if several magnets are used, distributed around the edge of the wheel, the wheel can be made to revolve. This is the elementary principle of direct current motors. Since a conductor carrying current acts like a magnet, the operation of the motor is that of mutual attraction or repulsion between two magnetic fields, provided the current in either is periodically reversed.

DC MOTORS

In the most common form of DC motor, there is an armature fitted with a commutator, so mounted that it is free to re-

volve. The armature will revolve in a magnetic field. If the motor is very small, made for very light use only, the field may be provided by a permanent steel magnet. For most ordinary purposes, however, electro-magnets are used to provide the field. When direct current is supplied to the armature windings, through the commutator, the conductors of the armature are magnetized. The position of the brushes on the armature is such that the armature revolves as a result of the interaction between its magnetism and the magnetism of the field poles. The motion of the commutator segments under the brushes changes the direction of current flowing in the armature. Thus the condition that caused the armature to begin to revolve is maintained and the armature continues to revolve as long as current is supplied.

The action may be more clearly understood by referring to Fig. 221. This illustration was intended to clarify the action of a DC generator equipped with a commutator. It will now be seen that there is no essential difference in construction between a motor and a generator, and that the principle of one is simply a reverse of the principle of the other. (In almost all cases, it is possible to use a motor as a generator, or a generator as a motor. Occasionally, the constructional details of a motor are such that it cannot be used as a generator or vice versa, but this is not the common case.)

Referring now to Fig. 221, Position 3, suppose current to be supplied to terminals 1 and 2.

The direction of rotation in the case of the motor will be the opposite of the direction in which the instrument revolves when it is used as a generator. In the illustration referred to the armature has stopped at a "dead center," inasmuch as it consists of only one coil. However, if this armature were set spinning by hand the right hand side of the coil would be attracted to the south pole of the magnet and the left hand side to the north pole. As the armature revolved the commutator would revolve with it, until the segments had reversed their position with respect to the brushes. When that occurred the direction of the current in the armature would be reversed. The magnetic field of the armature would reverse its polarity. Side

No. 1 of the armature would then be attracted by the north pole of the field magnet and repelled by the south pole. Thus the armature would continue to revolve until the motion of the commutator with respect to the brushes again reversed the direction of the current and recreated the original condition.

In the illustration referred to the armature has but a single coil and it is shown in this illustration lying in a position in which it cannot begin to revolve unaided. If however, there were more than one coil of wire this motor would possess starting torque. In practice armatures always have more than one coil of wire. However, it does sometimes happen that the magnetic attraction and repulsion effective upon some of the armature terminals is exactly counterbalanced by an equal force operating in the reverse direction upon other portions of the armature. When that happens the motor will "stick," and must be given a shove to start it. Such a condition can be remedied by shifting the brushes slightly so as to alter the distribution of current in the armature winding, and prevent the opposing forces from maintaining a perfect balance.

Counter Electro-Motive Force

Whenever a conductor moves in a magnetic field in such a way as to cut across the lines of force current is generated in that conductor. In the case of a motor, voltage will be generated in the armature windings as a result of the rotation of the armature. The direction of the voltage generated will be opposite to the direction of the applied voltage.

"The counter electro-motive force" developed by a motor is of the greatest practical importance in controlling the motor's operation. The effective resistance of the armature depends upon the counter-EMF rather than upon the actual resistance of the armature winding. Just as in any generator the voltage developed depends upon the speed at which the generator is driven so in a motor the counter-EMF is small while the speed of the motor is slow, and becomes very nearly as large as the applied EMF when the motor operates at full speed. The amount of current flowing in the armature is the result of an

effective driving voltage. This effective voltage is equal to the difference between the applied EMF and the counter-EMF generated within the armature. Thus if the applied potential is 110 volts and the counter-EMF is 90 volts the effective applied potential is 20 volts. However, if the counter-EMF at full motor speed is 90 volts, a moment after starting it may be very close to zero. During the short time that elapses between the moment the motor is started and the moment it reaches full speed an excessive current will flow in the armature because the counter-EMF has not as yet reached its full strength. In small motors that come up to speed almost instantly this fact is of little practical importance; but in larger machines that are slower in reaching full speed the interval during which excessive armature current flows may be long enough to burn out the armature winding. Such machines are set in action through a "motor starter," a resistance which limits the amount of current in the armature circuit during the time that the motor is gathering speed.

Circuits of DC Motors

DC motors are of five general types, described according to the circuits used to provide current to both the field and the armature. Commonly both field and armature circuits are provided with current by means of a single line. Obviously the field may be connected in parallel or shunt with the armature. The two may also be connected in series. Lastly there may be two fields, one in shunt and the other in series; this last arrangement is called a compound motor. If the current in the series field winding flows in the opposite direction to the current in the shunt field winding, so that the two magnetic polarities are opposed, the motor is called a differential compound motor. There are also interpole and compensating DC motors.

These different types of motors do not all act in precisely the same way but are made for different purposes. A series motor is used when a strong starting torque is required. A shunt motor maintains a more constant speed than does a series

type. Excellent speed regulation is obtained by use of a differential compound motor.

The Series Motor

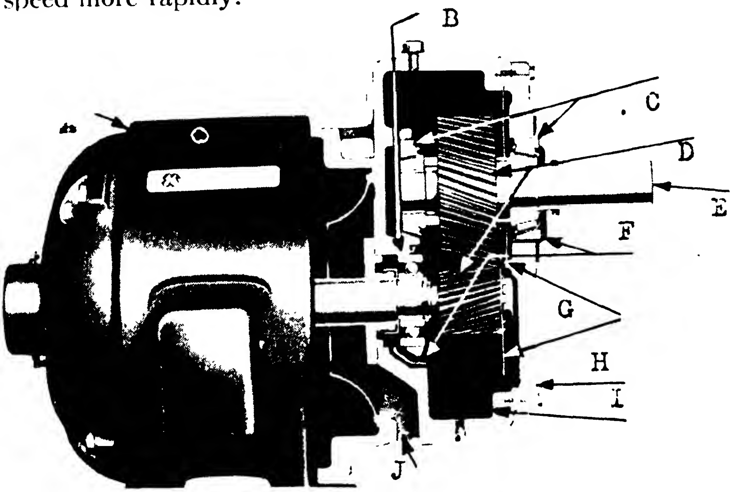
In the series motor all the current that passes through the field must likewise pass through the armature; all the current that passes through the armature must also pass through the field. The two circuits are one circuit. The amount of current flowing will depend upon their combined impedances and will be limited by the counter-EMF developed in the armature. At the moment of starting, when the counter-EMF is very low, a large current will flow through both the armature and the field. At this moment the magnetic strength of the field is very great and the motor possesses a powerful starting torque. This motor has a wide use in work that requires frequent and rapid starting, such as street car and electric railroad use. It is poorly adapted to most projection room purposes because its speed varies whenever the load upon its changes. The shunt type motor is steadier in operation.

Shunt Type Motors

In the shunt motor the field is connected in parallel with the armature. There are two circuits, not one. The amount of current flowing in the armature is controlled, as in the other type, by the impedance of the armature winding and by the counter-EMF developed as the motor revolves. But the current in the field windings remains nearly the same under all conditions, being governed by the impedance of those windings and by the driving voltage applied. This statement is not strictly true, but it is true for practical purposes, the effect of the armature in diverting current from the field being comparatively small. The starting torque of the shunt motor is not great, but the motor is comparatively steady in operation since its field strength remains substantially constant under all conditions of load.

Compound Motors

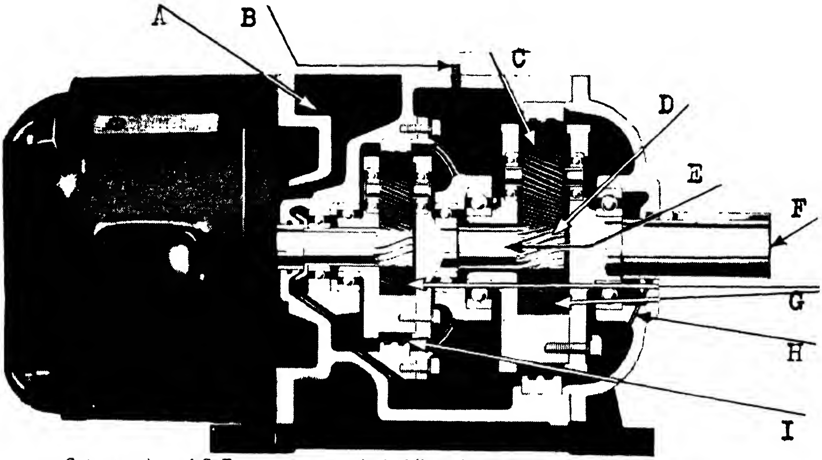
The compound motor has two field windings on each pole. In general the shunt winding does most of the work of driving the motor, but the series field, with its momentarily large current during the starting period helps bring the motor up to speed more rapidly.



A---Standard ball-bearing motor
B---Motor shaft supported by its own bearings
C---Gear output shaft
D---Helical gears
E---Outputshaft
F---Oil return grooves
G---Two disc-type oil slingers
H---Cast-iron housing
I---Oil well
J---Air ducts provide air to motor

The differential compound motor has very good regulation under large variations in load. The shunt and series field oppose each other. If an increased load is placed upon a shunt motor the armature tends to slow down somewhat, decreasing its counter-EMF. This will result in a somewhat increased flow of current through the armature, tending to bring it back to

normal speed. The differential series field assists this action. Since it opposes the shunt field in polarity, its effect upon the armature will be to generate in the armature an EMF in the same direction as the driving voltage, and opposed to the

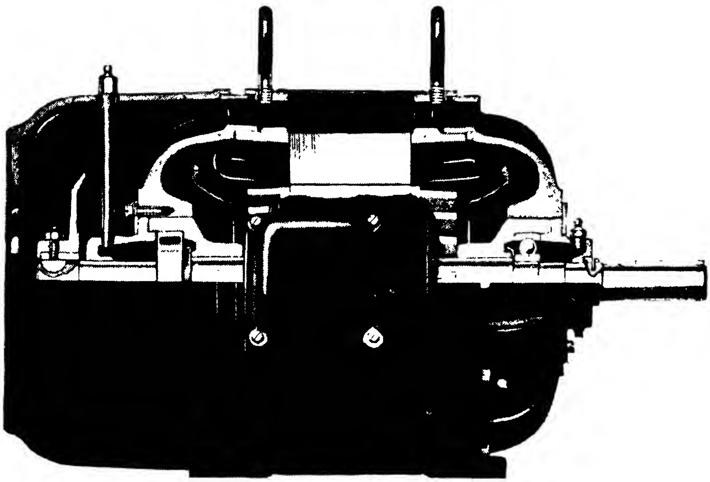


Cutaway view of G-E gear-motor, typical of "300 Series," double-reduction units

A---Air ducts provide air to motor
B---Oil filler plug
C---Two stage of double reduction gear
D---Low speed shaft of first stage
E---Low speed shaft of first stage, pressed and keyed into steel plate forming the outer head of planet cage
F---Output shaft and outer head of planet cage
G---Helical planet gears of second stage
H---Oil return groove
I---Semisteel stationary ring gears

counter-EMF developed by the shunt field. When an increased load is placed upon a differential motor the armature slows down, the counter-EMF developed by the shunt field is reduced; an increased current flows through the armature and therefore also through the series field; the EMF generated by the action of the series field is increased because the strength

of the series field is increased; a still larger current flows through the armature, and the motor returns to normal speed. When the load upon a differential machine is reduced, the armature tends to speed up, increasing its counter-EMF. This reduces the current flowing in the series winding. The EMF generated by the series winding is reduced, that reduction cooperates with the increase in the counter-EMF to reduce the amount of armature current flowing and bring the armature back to normal speed.



Sectional view of a totally enclosed, fan-cooled induction motor

Speed Control of DC Motors

It will be seen that the generator action of any motor in developing of counter electro-motive force is of the greatest practical importance in governing the speed of the motor. An

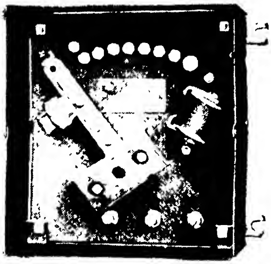
increase in field current amounts to an additional force that causes the motor to revolve, but also, to an addition to the force that generates counter-EMF. At operating speed the effect of increasing the counter-EMF is more important than the effect of increasing the field flux strength, and an increase in field current normally causes the motor to slow down. A *decrease* in field current causes the motor to speed up. Motors are ordinarily controlled with respect to speed by means of a rheostat in series with the field circuit. If the motor is compounded the rheostat controls the current through the shunt field. The rheostat is used to *decrease* the field current to make the motor run faster and *increase* the field current to make the motor run slower.

Interpole and Compensating Motors

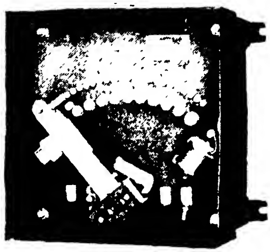
Normally the brushes of motors make contact with the armature at what are called "neutral" points, which are points where the fields of the different coils in the armature neutralize each other. At such points sparking between the brush and the armature will not take place. The exact location of the neutral points will shift about the commutator to some extent because of the interaction between the fields of the poles and the fields of the armature windings. The extent of the shift will vary with the strength of the armature fields; therefore with the strength of the armature circuit; therefore, to some extent with the load placed upon the motor. Whenever the load upon the motor is changed a tendency to sparking at the commutator results; this tendency is overcome by the use of commutating poles, or interpoles. The interpoles are placed midway between the field poles. They are connected in series with the armature. Whatever current flows in the armature current will also flow in the interpole windings. The interpole polarity is the opposite of the armature polarity; the interpole magnetic field is equal and opposite to the armature magnetic field: the action of the interpole field opposes that interaction between the flux of the armature and the flux of the field poles which causes the neutral point upon the commutator to shift position. The

interpole keeps the neutral point always at the same place, and therefore permits sparkless commutation under changing loads.

Where load variations are very great and the interpoles alone are not sufficient to give sparkless commutation, a compensating winding is placed upon each field pole. The current in the compensating winding assists the action of the interpole field in opposing any shift in the neutral point upon the commutator.



Armature resistor starter for accelerating D-c motors up to normal speed. As the contact lever moves over the stationary contacts, successive steps of resistor are cut out of circuit.



Compound starter for adjustable speed motors combines an armature resistor starter for bringing the motor up to normal speed and a field rheostat to obtain speeds above normal both operated from a single handle.

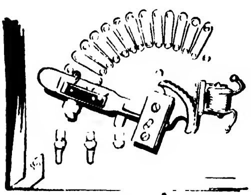
Separately Excited Motors

Excellent speed regulation can be obtained in a DC motor supplied with current from two different sources. If the source of field supply is entirely independent of the armature circuit the field current can be maintained substantially constant regardless of the action of the armature. This type of motor also possesses powerful starting torque when the resistance of the armature winding is small. Extremely delicate speed regulation can be obtained by means of a rheostat in the field circuit, and the motor will maintain constant speed in spite of comparatively large differences in load. The necessity for a separate source of constant voltage for the field supply complicates the problem of using such a motor in the projection room, and differential DC or synchronous AC motors are commonly preferred as projector drive motors, where no special speed control device is employed.

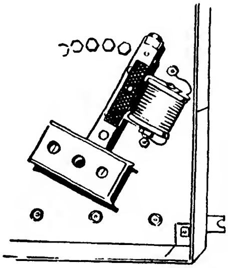
Universal Motors

The series motor described above is the most common type of Universal motor. It will operate with AC as well as DC, because at any given moment the field current and the armature current both flow in the same direction. When they reverse direction they both do so at the same time. At ordinary commercial frequencies the action of the commutator reverses the direction of flow in each armature coil a number of times during each 60 cycle alternation.

Ordinary DC motors will not operate with alternating cur-



Sliding contact type construction. Each contact segment cuts out a step of resistor as the lever passes over it.



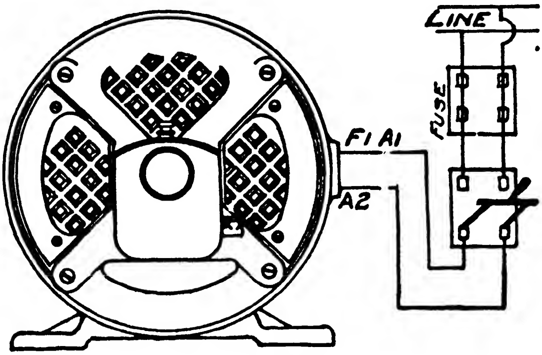
Low voltage protection prevents unexpected starting of machinery after voltage failure. An electro-magnet holds the lever in the "on" position. On low voltage the magnet releases and the lever returns to "off".

rent merely because the reactance of the field windings is too high to permit a sufficient amount of alternating current to flow. In the smaller type of motor especially, the motor manufacturer saves cost by making the flux path relatively inefficient and permitting the field coils to draw enough additional current to make up for the inefficiency. A motor intended for use as a universal motor has a more efficient flux path, made with better grade iron and more laminations to reduce eddy current losses. The amount of alternating current that flows through the field windings will be sufficient to operate the motor with a flux path of that kind.

AC Motors

AC motors are of almost innumerable variety, but the induction motor is the type most commonly used.

In the induction motor current is introduced into the armature not by means of brushes but by induction from the field windings. At the moment of starting the induction motor may be regarded as a transformer in which the field or stator plays the part of the primary and the armature the part of the secondary.



TWO LEAD MOTOR WITHOUT STARTER

The Rotating Magnetic Field

The stator winding is so arranged that when alternating current is applied to it each field pole reverses its polarity periodically as the direction of the current in it is reversed. Consider field poles numbered 1, 2, 3, and 4. At any given instant assume that No. 1 pole is north with respect to the armature; No. 2 is south, No. 3 north and No. 4 south. Now an instant later No. 2 pole will be north and No. 3 pole will be south/the effect being from the point of view of the armature very much as if the field were revolving. The result is that the armature or rotor revolves, following the rotating field.

Armatures may be of two kinds. The "squirrel cage" rotor consists of a grid work of interconnected copper bars embedded in an iron core. The wire-wound rotor is commonly

equipped with sliprings, which are used in the single phase motor to provide starting torque and sometimes to control the speed of the motor by means of a rheostat.

The rotor of an induction motor commonly follows a slight distance behind the rotating field, the exact distance depending upon the load the motor is required to drive. The description of the action of the rotor often given is that the rotor is "cushioned" by the revolving field. There is a certain amount of hunting in its action—that is small, brief variations in its speed—and a number of different methods for overcoming this effect are in common use.

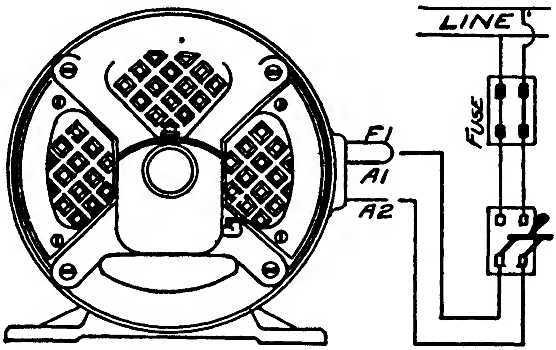
Synchronous AC Motors

The synchronous motor is an AC generator equipped with sliprings instead of a commutator. It will be remembered that the DC generator creates alternating current in its armature windings, and that this current is converted to direct current by the operation of the commutator. If sliprings are provided instead of a commutator and an alternating current is supplied to the armature the machine will function as a motor.

Consider any single conductor in the armature and any single field pole of the motor. Assume the conductor to be attracted to the field pole. At the moment when this conductor has changed its position until it is as close to that field pole as possible no further action can take place until the current through the conductor reverses its direction. There is now no commutator to effect this reversal in direction. Alternating current has been supplied through sliprings. The conductor therefore will not be repelled by the pole until the next alternation in the driving current. The conductor therefore passes one field pole for each alternation in the current supplied. The speed of the motor is consequently dependent upon the number of field poles and the frequency of the armature current.

In the case of the induction motor previously described, if the load is so heavy in proportion to the driving current that the motor falls far behind the rotating magnetic field the motor does not slow down, it simply stops. In much the same way in

the case of a synchronous motor the speed of rotation cannot fall behind the requirements set by the number of the field poles and the frequency of the alternating current supplied to the armature (it is remembered that direct current is supplied to the field). When the load is too heavy or the armature current available is too weak the motor stops. It cannot slow down.



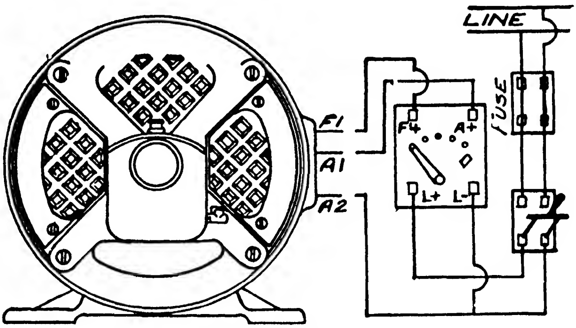
THREE LEAD MOTOR WITHOUT STARTER

Constant Speed Motors

The "synchronous" motors often used to operate electric phonographs or drive a projector are induction motors of special construction in which the rotor does not lag behind the revolving field but remains in accurate step with it. In effect it is the harmonic of the driving current and not the fundamental that is transmitted to the rotor by induction, and which causes the rotor to turn. If the load upon such a motor is made too great the motor stops; it cannot drag. These motors are not subject to hunting. The rotor is compelled to keep rigidly in step with the revolving magnetic field, which in turn will revolve at a speed that is determined by the number of field poles and the frequency of the current supplied.

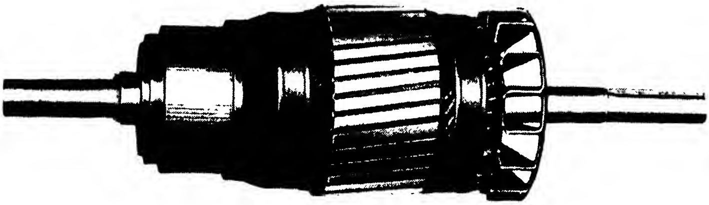
Repulsion and Commutating Motors

Repulsion and commutating motors are single phase induction motors equipped with a commutator. The effect of the commutator is to prevent the armature flux from coming exactly into line with the flux of the field poles. The commutator maintains a fixed angle between the two sets of lines of force,



THREE LEAD MOTOR WITH STARTER

the exact angle depending upon the position of the brushes. As the brushes are shifted the torque of this motor can be increased or decreased. In some cases the commutator is fitted with a centrifugal device that short circuits it when the armature reaches synchronous speed. Thereafter the machine operates as a pure induction motor.



Illustrating 20 to 60 Horse Power
Direct Current Sleeve Bearing Armature.

LIGHT

The subject of light is an all important one to the motion picture projectionist, in fact we can truthfully make the assertion that light is the most important subject both in the making and showing of motion pictures. Without light we would have no motion pictures, in fact without light we would have no life.

Either daylight or artificial light in the shape of high-intensity arcs, sun-light arcs, ordinary carbon arcs or mazda lamps is necessary to photographically record the picture on the film. Light is also used to register the sound on motion picture film.

In the projection rooms, light is again used to reconvert the photographed sound into actual sound waves, and light has always been necessary for the projection of the photographic image onto the screen.

A knowledge of the theory of light is necessary to help the projectionist understand the subject of optics as applied to the projector lenses, condensers and reflectors.

The subject of light is important as regards motion picture screens.

The question of light is an important one, when dealing with color films, as a matter of fact, color is nothing but light waves of different wave lengths. A knowledge of the theory of light will be of great advantage to any projectionist called upon in the future to handle television equipment, here not only light as applied to an arc lamp, photo-electric cells, reflectors, lenses, but also a knowledge of the action of light with regards to prisms, and perhaps, light as a carrier of sound waves.

THE NATURE OF LIGHT

"Light is the agent or force by the action of which, upon the organs of sight, objects are rendered visible" and, as such, it is imponderable; it has no physical body which would permit our senses to ascertain its nature, but it has certain effects on them, especially on the organs of sight. Also it is the source of certain physical phenomena which permit the expression of hypotheses and theories which lead to an understanding of its nature.

Several are the known sources of light; heat, electricity, chemical combinations, phosphorescence. As light is the direct consequence of one of these causes, it is quite evident that through the cause a certain disturbance is created, a stimulus which is, translated into the capacity of performing a certain work, *i.e.* into *energy,* which energy we call *light.*

Heat is one of the principal and most common causes of light. It has been ascertained that a non-luminous body, placed in the dark, begins to become visible when its temperature is rasied 500 to 600 degrees and that its luminosity increases with the increase of the temperature.

Such body, then, does not create light of itself, but by submitting it to the action of heat, it provokes a very special disturbance which becomes manifest as light only when heat has reacted upon the body in a certain quantitative measure, and is subject to variations, according to the (entity of this quantity).

The light emitted by the sun is the result of the extreme heat of its mass and of the state of incandescence of the vapors and gasses surrounding it. The temperature of the Sun has been estimated at somewhat below 6,000 degrees Centigrade nearly 11,000 Farenheit.

Thus, light is a force which is created, so to speak, by physical or chemical causes; it is not a permanent state of matter. Being created, it has a beginning. The stimulus starts at its origin, the source of light, and it *must travel* to reach the eye. How and what makes light travel has been one of the very first questions that Science has tried to answer and to this

day no positive answer has been made but the investigations carried on have given rise to theories or principles and suppositions which have received a certain confirmation as to their validity for they explain the phenomena pertaining to light.

Bodies are called transparent or opaque according to their faculty of permitting light to go through them, or by checking its course. In both cases some readily seen, and, thus measurable, phenomena happen.

When light encounters a transparent body, for instance, it is always deflected from its course and this deflection is constant for any portion of the same body and is always of the same order for all transparent bodies. This deflection of the light is then subject to some physical *Laws* which have been ascertained to be *always* governing the passage of light from one transparent body into another.

Likewise when light strikes an opaque body it rebounds and is reflected and the reflection is *always* subject to other *Laws* from which it never deviates.

Other phenomena pertaining to light are also found to be regulated by innumerable physical laws.

It is the study of these phenomena, the discovery of their effects, functions and governing laws which have been investigated and measured with great accuracy, and the relationship that has been found to exist among themselves and with regards to other fundamental laws regulating other physical phenomena such as *heat* and *sound,* has permitted science to promulgate the above mentioned theories and to sustain them by applying them to the explanation of all such phenomena.

Theory of Light Propagation

There are innumerable evidences that light is propagated in a *straight line.* A beam of sunlight entering a dark room through an opening in the shutter of a window forms a sun-spot on the opposite wall or floor of the room and this spot marks the continuation of the imaginary straight line joining the opening in the window and the sun. The shadow cast by

an opaque body makes a straight line with the body and the source of light, thus it can be stated that light *travels in a straight line.* As stated previously light originates from a source, light then must *travel with a certain velocity.*

It was at first thought that light was propagated by matter carrying the light energy. This gave rise to the *emission* or *corpuscular* theory. This theory, sponsored by Newton, implied the existence of infinitesimally small corpuscles which were *shot,* so to speak, from every point of the source of light in uninterrupted succession and in all directions at a great velocity. These corpuscles by impinging on the eye would provoke the sensation of vision.

Newton explained all known phenomena of light by the emission theory, but its truth was contested by Huygens, a contemporary of Newton, on the grounds that the emission theory implied an *increase* of velocity of the corpuscles when traveling through substances heavier than air. This was denied by Huygens and many years later was proved erroneous by Faucault, while investigating the velocity of light. In Newton's time the emission theory held good in spite of the great attention and interest paid to Huygens' disclosures.

According to Huygens light was not propagated by matter carrying the energy, but this *energy alone was transmitted* as a wave motion through stationary matter.

This theory implied the existence of a medium by virtue of which the light waves would be propagated.

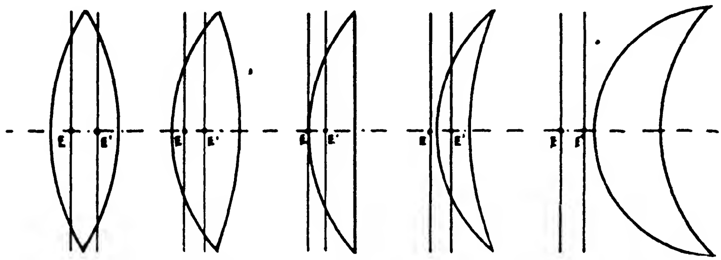
Huygens in his theory, surmised the existence of an extremely elastic fluid of infinite tenuity, filling all spaces and all matter.

Ether is the name applied to this fluid, which is supposed to fill all spaces in the universe. The ether must exist in the interstellar spaces beyond the earth's atmosphere, so as to permit the light energy emitted by the sun and the stars to reach the earth, as well as it must fill the infinitesimally small interstices between the molecules of all substances from the lightest gas to the heaviest metals.

Each point of a light source is supposed to become the center of a disturbance creating a spherical system of waves,

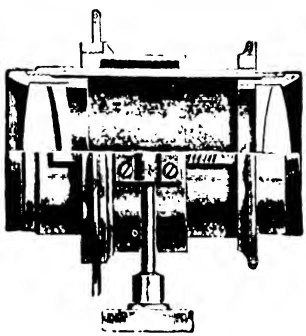
which thrown into the ether travel at a velocity first calculated by Roemer to be approximately 190,000 miles per second.

Each point of this spherical system is supposed to become itself the center of a disturbance and thus create its own system of secondary waves, thus forming an unlimited complex of spherical systems of waves within a sphere, whose center is the luminous point. The outmost boundary of the main sphere is called the *front wave.*

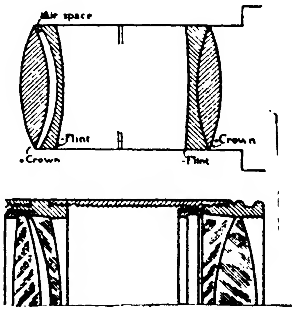


Principal points and planes in convergent lenses

BACK



FRONT

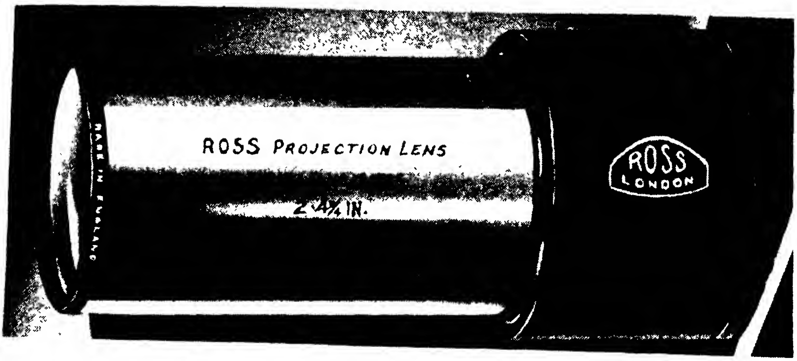


Huygens presented his theory at the French Academy of sciences in 1678 and through it gave a physical and mathematical explanation of nearly all known phenomena pertaining to light. The theory received the appellation of *undulatory theory* due to the undulatory progression of the waves.

Newton challenged the truth of the undulatory theory in favor of the emission theory because Huygens could not satisfactorily explain the rectilinear propagation of light.

This, and the difficulty in which Huygens found himself to give an explanàtion of the phenomenom of *diffraction,* which is the name given to a certain displacement of the course of light rays passing in contact with a sharp edge, held back the adoption of Huygens' theory, although its vast scope and the solidity of the argument held preeminent in the mind of the scientific world.

In later times, Fresnel, (1802) succeeded in proving the approximate rectilinear propagation of light by the wave theory and in expressing such a thorough explanation of the phenomenom of diffraction that it proved the ultimate argument in favor of this theory. The emission theory was then entirely discarded.



Fresnel admitted the existence of the *luminiferous ether* stating that its density is constant within the same substance or medium but varies from medium to medium and, by considering the light waves as elastic waves, such as those visible in a taut cord set to vibrate, he could establish the law that the velocity of light in any medium is inversely proportional to the square root of the density of the ether inside that medium. The importance of this law and the influence of the acceptance of the undulatory theory in the scientific world, will become evident throughout the study of the phenomena of

Clerke Maxwell Electro-Magnetic Theory

In the year 1865, Clerke Maxwell expressed the *electro-magnetic* theory of light, based upon the relation he discovered to exist between the specific induction capacity of the *dielectrics* (non conductors of electricity) and the influence that these substances have on the velocity of light traveling through them.

Clerke Maxwell tended to prove that the *medium in which luminous and electrical actions are transmitted, is the* same, and that there is an impulsive power, or motion as well as energy in the light waves.

The velocity of light in air was calculated by him by purely electrical means and he gave the result as 299,300 kilometers per second as compared with the mean of 299,800 kilometers obtained by direct observation.

This remarkable result led Maxwell to state that light *is an electro-magnetic* wave and, although he succeeded in calculating the pressure exerted by the momentum of the light waves, he could not prove the existence of the electro-magnetic waves.

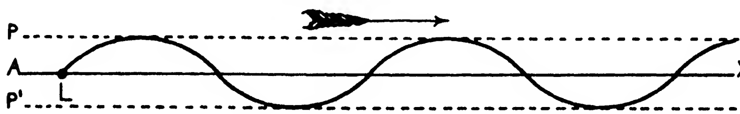
His reasoning was purely mathematical and as no phenomena could be explained by the electro-magnetic theory that could not be explained by the undulatory theory the former was little considered until Hertz, from 1888 to 1892, proved that magnetic intensities are propagated at a measurable and thus finite velocity and succeeded in producing and giving proof of the existence of electro-magnetic waves.

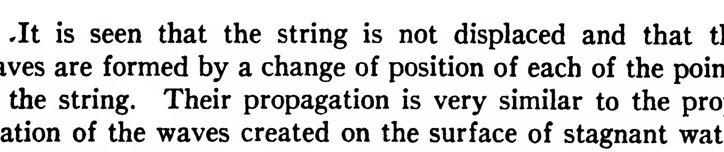
Since Hertz disclosures, the electro-magnetic theory obtained great favor in the scientific world, but as the undulatory theory can still be used in treating of the phenomena of light that are of interest to the readers of this work and in a more intelligible way, as it avoids the mathematical calculations involved in the Maxwell theory, we will not depart from it, referring the reader to the special literature treating the more modern theory.

LIGHT WAVES

The acceptance of the undulatory theory involves the existence of waves, propagating the energy emitted by the luminous body.

The simplest example of wave motion is that of the vibrations imparted to a taut string. If a shock is produced at one end of the string the whole string is set into a vibratory motion which from its start, at the point where the disturbance is first created, is propagated to the other end and is continuous, until the influence of the disturbance ceases to have effect and the string is again in a state of rest.





It is seen that the string is not displaced and that the waves are formed by a change of position of each of the points of the string. Their propagation is very similar to the propagation of the waves created on the surface of stagnant water by any disturbance.

The appellation *waves* is applied to all disturbances in which a particular state of a medium is brought on without change in the medium and it originates from the familiar effect of waves produced on the surface of water.

Suppose that a cork is lying on the surface of a calm pool and the surface of the water is touched at any other point by means of a stick or by throwing a pebble into the pool. A circular system of waves will be formed having as center the

point of disturbance. These waves will have a *transversal* motion and gradually enlarge their circle, the extreme boundary of which will at any definite time mark the *wave front* of the disturbance. When these waves reach the cork the latter will be seen to follow the transversal motion but to remain in the same spot. Light waves are propagated in a very similar manner.

The undulatory motion of the waves may be illustrated in the following manner:

Let the line A X represent a taut string and let a disturbance be created at the point L. The vibrations of the string thus set in motion would be propagated in the direction marked by the arrow and in the form shown by the curved line in the figure. Their amplitude would be limited by the dotted lines P and P′.

Every point of the string will then successively take all of the positions included in the curved line A E and just as the cork floating on the disturbed surface of water, would follow an up and down movement. The distance A E includes then a *whole wave* and establishes the *wave length.*

It is quite evident that all points of a wave execute a movement at the same time, but not in the same direction.

The points B and C, for instance, are moving in opposite directions, but for each consecutive wave there are always points moving in synchronism, such, for instance, the points A and E.

The points A and E are said to be in the *same phase* while the points B and D are said to be in *opposite phase.*

The length of the light wave has, as will be seen later, a marked influence on the quality of the light, as waves of different length have a different repercussion upon the eye and establish the different sensations called *colors.*

As the light waves are propagated with a finite velocity it is easily understood that other quantitative entities can be expressed and this in respect as to time and space.

The first of these entities is the number of waves that are created in a certain fixed time. This has been called the *frequency* and the time has been fixed to a second.

The second entity is the number of waves contained in a certain fixed distance between two points of the train of waves. This distance has been fixed to the centimeter and the attribute is called the *wave number.*

A clear understanding of the above is extremely important in the study of the phenomena pertaining to light and can be resumed as follows:

Wave length:—The cycle representing the motion of a complete wave (A E in the figure).

Wave:—The number of vibrations in a second.

Wave number:—The number of waves contained in a centimeter.

The Velocity of Light

Although the propagation of the light waves in the ether takes place with an extreme velocity, human ingenuity has accomplished the almost incredible feat of measuring it with a great degree of accuracy.

The first accurate measurements of what is called the *velocity of light* were obtained by the Danish astronomer Ole Roemer in 1675 through the observation of the occultations, or eclipses, of one of the four, then known, satellites of the planet Jupiter at six month's interval of time.

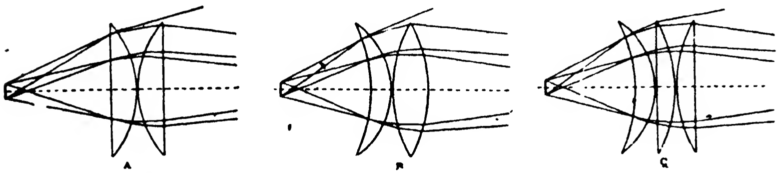
Roemer's calculations gave as results 304,000 kilometers or 190,000 miles per second.

This figure is somewhat higher than the results obtained more recently and by other methods, this being due to several factors that escaped Roemer's attention at the time he conducted his investigation, which factors have been brought about by a better scientific knowledge of light phenomena.

In order to avoid errors inherent to astronomical observation Fizeau and Foucault devised a means by which the velocity of light can be computed by terrestrial observation.

Fizeau, by this method calculated the velocity of light to be 313,600 kilometers or 196,000 miles per second, a figure also in excess of more recent computations.

Foucault, constructed in 1850 an apparatus which gave more reliable results because of the different order of measurement involved. Foucault's apparatus is remarkable by the fact that no great distances are necessary, the whole length of it being approximately 20 feet.



Types of Condenser Lens Combinations—A, Double Plano-Convex; Meniscus-Bi-Convex; C, Meniscus Double Plano-Convex

Professor Michelson in 1924 and 1927 conducted a series of computations with apparatus recalling the Foucault's and Cornu's systems.

The following descriptions are abstracts from Professor Michelson's reports published in the *"Astrophysical Journal (60, 256, 1924 and 65, 1, 1927)"*:

"A beam of light from a Sperry arc at a station on Mt. Wilson (California) is reflected from one face of an octagonal rotating mirror to a mirror located on Mt. San Antonio about 22 miles away whence it is reflected back to the originating station where it is reflected by the next succeeding face of the rotating mirror into a micrometer eyepiece.

"The velocity of the light is ascertained from the rate of rotation of the mirror.

"The advantages of the method are; *a*) greater distance between the stations; *b*) sufficient light for accurate measurements; *c*) elimination of the measurement of angles."

Professor Michelson, proceeds further to tell that as the distance of 22 miles requires 0.00023 seconds for the light to go and return, "during this time the mirror making 530 turns per second, will rotate through one eighth of a turn thus presenting the succeeding face to the return light at the same angle as though it were at rest.

"The observation will then consist in obtaining this speed, in the present case, by stroboscopic comparison with an electric fork making 132.25 vibrations per second. The latter being controlled by comparison with a free seconds pendulum."

"The light source of the Sperry arc is focused on the slit *s′*. Falling on the face *a* of the octagon, the light is reflected to a right angle prism *b*, to another at *c* whence it proceeds to the concave mirror *d* of 24 inch aperture and 30 foot focus. This reflects the pencil as a parallel beam to the distant mirror (also a 24 inch 30 foot concave) proceeding thence to a small concave reflector at its focus. An image of the slit is formed at the face of this small reflector which necessitates the return of the light to the concave *d* whence it passes over the prism at *c* to *b* whence it is reflected to the face *a′* of the octagon forming an angle as *s′* where it is observed by the micrometer eyepiece M."

This method permits the evaluation of the velocity of light, with results probably correct within one part in ten thousand.

The results obtained by Professor Michelson in 1924 were 299.820 kilometers or 187.388 miles per second in vacuo.

Professor Michelson made computations in 1927 for which "the arrangement of the apparatus differs slightly from that of the former investigation, allowing a more nearly normal incidence on the facets of the revolving mirror and providing greater symmetry as well as increase in illumination.

"Five independent series of measurements made with different revolving mirrors (one of steel having the form of a prism with eight facets, and another with twelve and three of glass with eight; twelve; and sixteen facets) gave results showing a remarkable agreement."

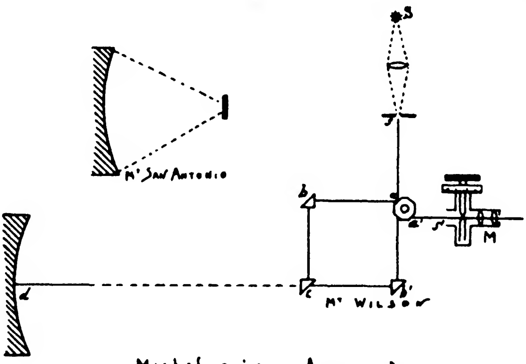
Glass:	*8 facets*	*299.797 km. per second in vacuo*
Steel:	*8 facets*	*299.795 km. per second in vacuo*
Glass:	*12 facets*	*299.796 km. per second in vacuo*
Steel:	*12 facets*	*299.796 km. per second in vacuo*
Glass:	*16 facets*	*299.796 km. per second in vacuo*

The following table gives the results obtained by several

scientists during a lapse of time covering over 250 years. These figures have a truly amazing significance when consideration is given to the slight differences in the results obtained in such a delicate undertaking.

VELOCITY OF LIGHT

By	In the Year	In Vacuo Kilometers	In Vacuo Miles
Ole Roemer	1675	304.000	190.000
Fizeau	1849	313.600	196.000
Foucault	1850-1862	296.257	185.157
Clerke Maxwell		299.300	187.062
Michelson	1880	299.908	187.443
Young and Forbes	1882	301.382	188.314
Newcomb	1882	299.860	187.413
Cornu	1900	300.400	187.750
Michelson	1924	299.820	187.388
Michelson	1927	299.796	187.373



Michelson's Apparatus

LUMINOUS; NON-LUMINOUS; OPAQUE; TRANSPARENT AND TRANSLUCENT BODIES

All bodies can be divided into two classes, ***Luminous*** and ***non-luminous***. As we have stated bodies become luminous under the influence of some action of physical or chemical order. A body is then said to be luminous when this influence is acting upon it and is thus creating the light energy.

Bodies in the non-luminous state are said to be *transparent*, *translucent* or *opaque*. Substances that readily permit the transmission of light and through which objects may be seen are called *transparent*. Gases, clear water, polished glasses are transparent bodies. Substances which transmit light, but through which objects cannot be distinguished, are called *translucent*. Ground glass, porcelain, etc., are translucent.

Transparent and translucent bodies receive the generic name of *media*. So a ray of light is said to travel through the *medium* air and to pass from it into the *medium* glass. The surface of the glass becomes the boundary between the two media air and glass.

Substances which do not permit the transmission of light are called *opaque*. Metals, wood, stone, etc., are opaque bodies.

There are no perfectly opaque nor perfectly transparent bodies. Consider, for instance, water as a highly transparent substance. A sufficient thickness of water, no matter how pure it may be is quite impenetrable by light and, on the other hand, when gold is reduced to a very thin leaf, it transmits a green light.

It is quite evident that if an energy or force propagated by a constant motion in a certain definite direction meets an obstacle in its course something is bound to happen. When a rubber ball is thrown against a wall, it rebounds from it with a speed almost equal to the speed imparted to it by the thrower. A stone thrown against the same wall also rebounds from it, but at a speed greatly less than that of the rubber ball. If a stone is thrown into water it goes through the water but its speed is lessened.

When the light energy meets an obstacle in its path, similar phenomena happen and the study of these phenomena and the laws governing them are part of that branch of physical science called *optics*.

Light Rays

All luminous bodies create the energy called light and this

energy has been shown to be propagated in all directions. It is quite evident that this energy presents the same properties at every point where it is propagated. The light energy emitted by an electric bulb placed in the center of a room has the same characteristics in all corners of the room and if it is desired to learn some of its intrinsic properties, it will be sufficient to investigate them at any one point of the room. It was thus found necessary to establish a minimum entity of light energy, the knowledge acquired on its behavior standing good for all other similar entities of the same source of light.

As light is propagated in a straight line we can imagine *one definite point* of the luminous body creating the light energy and from this point the portion of this energy which reaches another point at any distance from it. This quantity of light energy receives the name of *ray*.

A *ray* of light is then an imponderable entity of light representing the *direction in which light is propagated.*

When the light of the sun is permitted to pass through a small orifice drilled in the wall of a dark chamber and the chamber is filled with a thin cloud of smoke a streak of light is made visible which is commonly called a ray. This streak, in fact, no matter how small the orifice may be, is composed of an infinite number of rays. Such an agglomeration of light rays is called a *beam* or *pencil of light.*

The path of a ray of light in any substance can be followed with great precision and a visual representation of it can be drawn on paper. In such representation, a ray of light is always represented by a straight line.

White light is, as will be demonstrated later, formed by the amalgamation of lights of different colors. The lengths of the wave of the colored lights differ among themselves and their behavior varies in accordance with the nature of the transparent body they are traversing. It is then necessary not only to consider the segregation of a single ray of light, but also the segregation of a ray of a *certain wave length.* In the following chapter a ray of light shall always be construed to be a ray of *monochromatic* light, or light of *one color.*

REFLECTION OF LIGHT

WHEN a ray of light impinges upon the highly polished surface of an opaque body the greatest portion of its light rebounds into the medium in which it was traveling and it is said to be *reflected,* and a small portion of it is absorbed by the opaque body.

Some of the reflected light follows a definite path in obedience to definite laws and it is said to be *regularly reflected;* some is irregularly reflected and it is called *scattered light.*

All opaque bodies absorb and reflect light and it is through the phenomenom of irregular reflection that they are made visible. The light that is regularly reflected gives us the image of the luminous source while the light that is scattered in every direction from every point of the reflecting surface acts upon the eye as if each one of these points was a light source, and, therefore, forms their image in the eye.

The ray of light impinging upon a reflecting surface is called the *incident ray* and the ray that rebounds from the surface is called the *reflected ray.*

The regularly reflected ray of light, follows two laws which are expressed as follows:

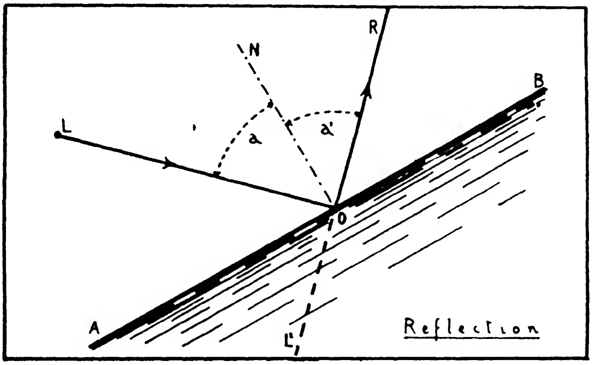
I: *The angle of reflection is equal to the angle of incidence.*

II: *The incident and the reflected rays are both in the same plane which is perpendicular to the reflecting surface.*

The truth of these laws can be proven by several physical experiments, the best known and the one which is perhaps the most susceptible of great accuracy is as follows:

A small telescope is set upon a graduated disc which is placed in a vertical position. The telescope is aimed at a plainly visible star and its position is read on the scale of the disc which corresponds with the optical axis of the telescope.

A vessel filled with mercury is placed at a suitable distance from the telescope. From its former position, the telescope is aimed at the image of the star reflected by the mercury. A reading is also taken on the graduated disc and it will be seen that the two lines drawn from the center of the axis of revolu-



tion of the telescope to the readings obtained form two equal angles with the horizontal passing through the same center. An elementary geometrical construction proves that the angle made by the light rays of the star with the normal to the mercury surface is equal to the angle made by the reflected light with the same normal.

The second law is proved by the arrangement of the apparatus itself.

The truth of these laws render possible the geometrical construction of a reflected ray.

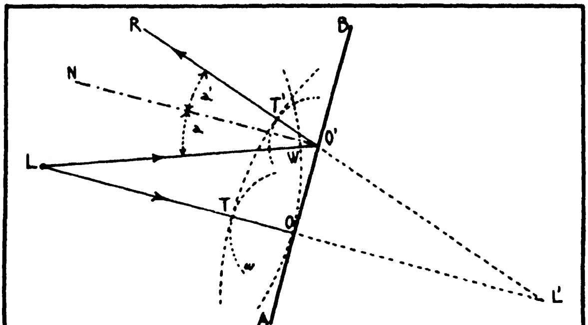
Let A B represent the surface of a reflecting body; L a luminous point source of light; L O a light ray incident upon the surface at the point O, and let the plane of the paper be the plane of reflection. At the point O, draw the normal O N to the surface A B.

The ray L O and the normal O N, will subtend the angle of incidence *a*. If we trace the line O R so that it makes with the normal an angle *a'* equal to the angle *a*, the line O R will indicate the direction of the reflected ray.

If the eye is placed at R, the luminous point will be seen as if it was located at L′, on the prolongation of the reflected ray and at a distance from O, equal to the distance of the luminous source to this same point.

Another construction can also be arrived at by following Huygens' theory.

Let L be the luminous point and A B the reflecting surface and let the ray L O be perpendicularly incident upon the surface at the point O. All the rays emanated by L will present a wave front W. As soon as the ray strikes the surface at O it is reflected, and according to the theory, the reflected ray forms its own system of waves and at a certain time these waves of reflected rays will present the wave front *w*. Let us consider now another ray emanated by the luminous point L and let it be the ray L O′. By the time the first ray L O has reached the point O this second ray will have reached only the point W so it will strike the reflecting surface somewhat later than the ray L O and at the time the wave front of the reflected rays at *O* will have reached the point T, the wave



Huyghen's construction of reflected rays

front of the ray reflected at O′ will have reached only the point T′ This secondary wave front has a radius equal to T O less W O. According to Huygens' theory, the wave fronts of their reflected rays are spherical and are complimentary to the wave front formed by all of the rays reflected from all

points of the reflecting surface. It is then only necessary to find the sphere which is tangent to both these secondary spheres to obtain the principal wave front found by *all* the rays reflected by the surface. By a simple geometrical construction, the principal wave front is found to touch the secondary ones at T and T′. It is then found that the center of this sphere is at *L′* on the prolongation of the ray L O and that L and L′ are at the same distance from O. It is also found that the ray L O is reflected upon itself and that the ray reflected at O′ cannot follow any other path than the path O′ R. If we now draw the line O′ N normal to A B at the point O′, it can be geometrically proven that the angles *a* and *a′* are equal. Now the angle *a* is the angle of incidence and the angle *a′* is the angle of reflection in respect to the ray under consideration and their equality is in accordance with the first law of reflection. The arrangement of the figure proves the truth of the second law.

When the luminous body is at a great distance from the reflecting surface, such for instance as the Sun in respect to a mirror on Earth, the radius of the sphere presenting the principal wave front is so great, that the wave front can be considered a straight plane.

Intensity of the Reflected Light

It is quite obvious that, due to the partial absorption and scattering of the light propagated by the luminous body, the intensity of the reflected light is *less* than the intensity of the incident light.

The intensity of the reflected light is also dependent upon the nature of the reflecting surface, its degree of smoothness and upon the obliquity of the incident ray.

The power of absorbing light varies with different substances and this influences the visual brightness of each substance as well as the intensity of the light reflected by them. The highly polished surface of a silver mirror reflects more light than the equally smooth surface of a sheet of paper.

If a reflecting surface is very coarse, it presents to the incident light a great number of small surfaces under an in-

finite variety of angles and consequently the reflected light is so divided by reflection in so many directions that its intensity is much less than the intensity of the light which would be reflected by a highly polished surface of the same substance.

Less commonly observed but easily verified is the influence exerted upon the intensity of the reflected light by the obliquity of the incident ray in respect to the reflecting surface. If we stand on the shore of a large body of water, such as a tranquil lake, we can readily observe that at high noon when the Sun is approximately at the zenith we can look at the water without being disturbed by any glaring reflection. As the Sun nears the horizon the reflected light becomes stronger and stronger till in the late part of the day the light *glare* from the water is so intense that the eye can hardly look directly at it.

Refraction of Light

When a ray of light which is being propagated in a medium of a certain density encounters a transparent medium of a different density it passes through it, but its course is deviated. This phenomenom is called *Refraction.*

The light that is refracted is as in the case of reflection, of *less* intensity than the incident light, due to the fact that a small portion of it is reflected by the boundary surface, some of it is scattered and some of it is absorbed by the refracting medium.

It has been stated previously that Foucault has proved conclusively that light suffers a diminution of its velocity when passing from a medium of certain density into a medium of greater density.

This diminution of velocity is due to a constant dying away of the light waves while they pass through such dense medium and their constant replacement by new waves.

The speed required to carry the wave crest from A to B, is termed the wave speed.

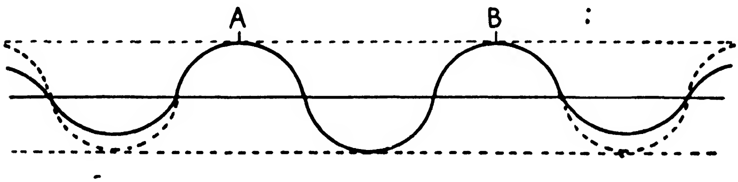
The dotted line in the figure illustrates the behavior of light waves in vacuo. When light passes through a dense medium its front wave continually dies away as shown by the

full line in the figure and is constantly replaced by the following waves each of which proceeds further than the preceding one while new waves are constantly forthcoming from the light source.

The dying away and replacement of waves results in a retardation of their velocity.

A group of waves as illustrated in the figure moves then at a lesser speed than the individual wave and its speed is inversely proportional to the density of the medium.

The change in *velocity* is cause of a change of *direction* of the light ray and this change of direction takes place *at the surface* of the second medium. From this surface the light travels in a straight line throughout the medium, providing the latter is homogenous.



Light Wave - group

REFRACTION AT CURVED SURFACES

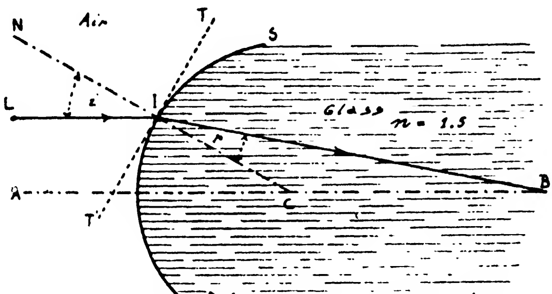
A curved surface is called *convex* if it presents its bulging face to the source of light or *concave* if it presents a hollow or incurvation towards the source of light.

The simplest form of a curved surface is the sphere or that surface all the points of which are equally distant from a point within, called the center.

The principal section of a sphere passes through its center and is a circle. A straight line which touches the surface of the sphere, but does not cut through it, is said to be tangent to the surface and is always perpendicular to the radius of the sphere which joins its center with the point of tangency

Let us suppose now a medium glass having a spherical convex surface.

Let S S′ be such surface and L a luminous point source of light incident upon the surface of a portion of a glass sphere



Refraction at a convex surface

at the point I. Let the two media be air and glass as indicated in the figure. At C is the center of the section of the sphere of which S S′ is part. The line C I represents the radius of the sphere and the line T T′ perpendicular to it at *I*, is tangent to the surface of the sphere and consequently touches it in one point only.

The point I can then be considered to be common to the spherical surface and to an imaginary plane surface of a medium which possesses the same structure as the medium of the sphere.

The incident ray will then be refracted within the sphere, according to the laws of refraction, making with the normal N C an angle of refraction *r*, answering to the condition

$$\frac{\sin i}{\sin r} = \frac{n'}{n}.$$

The ray refracted by a convex surface will then always converge towards the axis A B.

If the refracting surface is concave, that is to say if it presents a hollow to the source of light, the same reasoning can be followed and it is found that the refracted rays are always divergent from the axis.

Let S S′ be the concave refracting surface. C its center and T T′ the tangent to the surface at the point I.

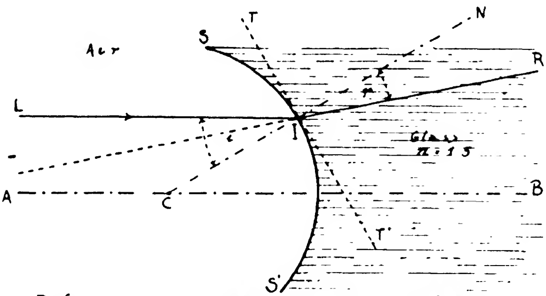
Again the tangent T T′ can be considered as the imaginary plane surface of a body having the same refractory characteristics as the body in question.

The refracted ray can then be traced geometrically and according to Snell's law.

The angle *i* and *r* are found to be respectively the angles of incidence and the angle of refraction and the refracted rays always diverge from the axis A B.

In all the examples shown so far in the figures, the source of light has always been supposed to be situated in the medium air and to follow a certain path which we have usually traced as from left to right.

In the illustrations of the phenomena of reflection and re-



Refraction at a concave surface

fraction we can always suppose the source of light to be situated at any point of the reflected, or of the refracted ray. The path of propagation of the rays would thus be reversed but it would follow the same idèntical direction.

In the case of reflection the angles of incidence and reflection would evidently be reversed but be equal in size.

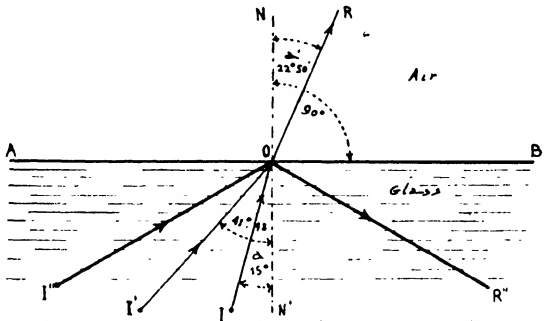
In the case of refraction the incident ray would lie in the denser medium and would therefore, make an angle of refraction greater than the angle of incidence when passing from the denser into the lighter medium.

The path followed by a ray of light is then *reversible,* and

when investigating it, the stimulus may be placed at any point along its course, and its direction can be reversed at will.

Total Reflection

Let us consider a ray of light whose origin is within a medium denser than the medium into which it emerges.



Total Reflection and Critical angle

Let us suppose A B to be the boundary surface between glass and air and let a luminous point source of light be placed at I within the glass, making an angle of 15° with the normal to the surface A B.

According to the law of refraction the ray when emerging from the glass at O will be refracted in the direction O R making with the normal angle of 22° 50′ if the index of refraction of the glass is 1.5.

As the ray leaves a dense medium to enter a rarer one the angle of refraction is greater than the angle of incidence and, consequently, a certain amplitude of the angle of incidence can be found at which the refracted ray will make an angle of 90° with the normal to the refracting surface.

With the chosen glass, this angle will be found to be of 41° 48′ and it is called the *critical angle* for that particular variety of glass.

If the incident ray makes with the normal an angle of incidence greater than the critical angle of the medium in which it is traveling, the ray cannot emerge from the medium and is *reflected* back into the medium making with the normal, according to the laws of reflection, an angle of reflection equal to the angle of incidence.

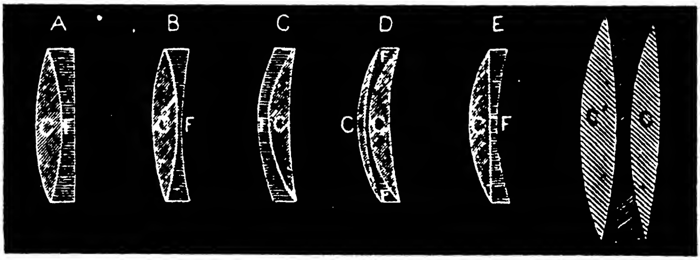
Under such conditions the ray is said to undergo *total reflection* because no loss of intensity occurs from absorption or scattering, as is the case in normal reflection.

It is evident that the critical angle of a medium varies according to the density of the medium and it is smaller the denser the medium is.

Thus, for instance, a diamond is the denser of all transparent media and consequently a greater amount of the light entering it, is totally reflected than in any other transparent medium. This accounts for the unequalled brilliancy and sparkle of this gem.

Refraction Through a Glass Plate

We have thus far considered the changes in the direction that a monochromatic ray of light suffers when impinging



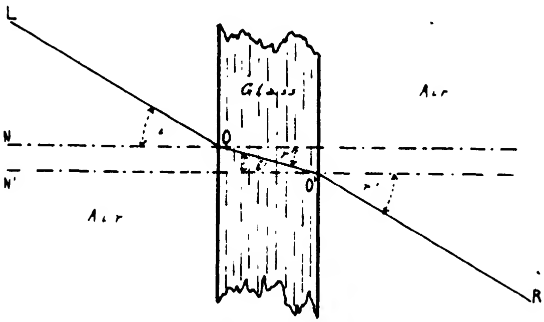
upon a reflecting or a refracting surface. We shall now consider the effect that transparent bodies, having a definite shape confined within definite boundaries have on light incident upon their surfaces.

For the sake of clearness we shall avoid at first the com-

plexities inherent to the composition of white light and we shall consider throughout this chapter only rays of monochromatic light or light of one color.

The simplest of such bodies is a glass plate with parallel faces. We shall suppose such a plate having certain thickness and to be placed in air. Let a ray from a monochromatic light source strike it at any of the points of the surface and under an angle of incidence of any desired magnitude.

Let the ray be emanated by a luminous point source L and strike the first surface of the glass plate at O, making with it the angle of incidence *i*.



Refraction in a glass plate with parallel faces

According to the laws of refraction, the ray will change its course within the plate and follow a direction O O′, making with the normal N the angle of refraction *r*.

And we have expressed previously the index of refraction from air to the particular glass used is given by the ratio $\frac{\sin i}{\sin r}$. After traveling within the glass at a reduced velocity the ray will strike at O′ the surface of the medium *air* in which the glass plate is supposed to be placed.

At this point then, the ray emerges from one medium to enter a rarer one. Again it suffers a change of velocity and as the medium *air* is less dense than the medium *glass*, this velocity will be increased and resume the normal velocity of light in air. The angle *i′* is then the angle of incidence and

the ray at its exit from the glass will form an angle of refraction r'. It is evident that the index of refraction from glass to air is equal to the ratio $\frac{\sin i'}{\sin r'}$ which is the reciprocal of the index of refraction from air to glass. The angle of refraction r' is in this case greater than the angle of incidence.

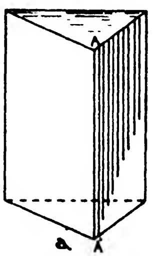
The geometrical construction of the refracted ray O′ R proves that this ray emerges from the glass following the direction parallel to the incident ray L O.

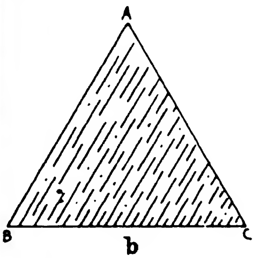
Refraction Through a Prism

In optics, any transparent medium bounded by three plain surfaces inclined to each other is called a prism.

The line A A′ at the intersection of two faces is called the *edge* of the prism. The principal section of the prism which is perpendicular to the edge A′ is a triangle. This section is shown at *b* in the figure. The point A is called the *summitt*. The line B C is called the *base* of the prism and the angle B A C is the refracting angle.

As in the prism, the two refracting surfaces are inclined to each other, it is evident that if the prism is surrounded by air a ray of light cannot be refracted by it so as to emerge





into air in a direction parallel to the original incident direction as it was the case with the parallel refraction surfaces.

As the ratio between the angle of incidence and the angle of refraction is constant for the same two media, it is possible

when these indexes of the two media are known, to geometrically construct the path of a refracted ray corresponding to a given incident ray.

Angle of Minimum Deviation

Let us set a prism in a dark room, and let a very small pencil of light from a distant small opening, be refracted by it, under a large angle of incidence. An image of the small opening can be seen on a screen placed at a certain distance from the prism.

Let us now gradually turn the prism so as to decrease the magnitude of the angle of incidence. We notice that the image of the opening on the screen displaces itself up to a certain position from which it returns towards its original one, though the prism is still rotated in the same direction.

This experiment proves that there is for the prism a certain angle at which the total deviation of the refracted ray is at a minimum.

Let us consider rays of monochromatic light incident upon the surface A B of a prism at different angles of incidence and for the sake of clearness we will draw three separate figures of the same prism.

a b c
Angle of minimum deviation

Let the prism A B C be made of glass, of an index of 1.5 and let the surrounding medium be air.

Let the incident rays make with the surface A B three angles of incidence of different magnitude.

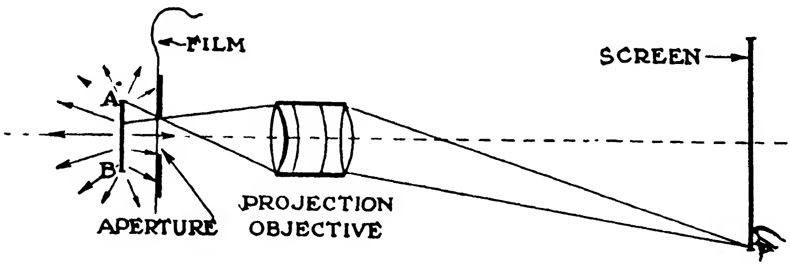
Following the same geometrical construction, which has

been previously proven to be true, we can trace the paths of the refracted rays within the prism and at their exit from it.

It will be noticed that while the angles of incidence decrease in magnitude, the corresponding angles of deviation do not decrease proportionately. To the contrary the angles of deviation in figures *a* and *c* are both *greater* than the angle of deviation in fig. *b*.

For a prism there is then a certain angle at which the deviation of the rays is less in magnitude than for any other angle. It can be mathematically proved that this *angle of minimum deviation* occurs *when the angle of incidence and the angle of emergence are equal* and that the ray within the prism follows a path equally inclined to the two faces of the prism.

If the small opening which allows the passage of the pencil of light incident upon the face of the prism is looked at through the prism by virtue of refraction, it will be most clearly seen when the rays have followed the path of minimum deviation.



Source Size Requirement— Source A B must be larger than the aperture to send light through a point at the edge of the apeerture and through the full opening of the objective lens

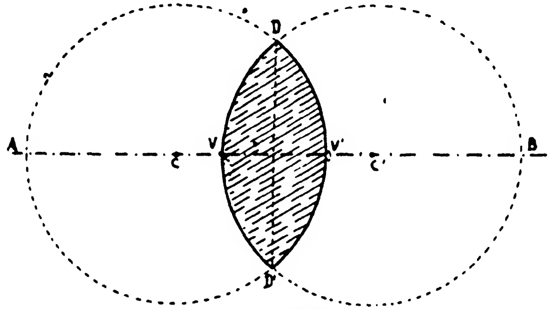
Refraction Through Lenses

A lens is a refracting medium of homogeneous composition bounded by two curved surfaces.

Lenses are named according to their shape so if their surfaces are portions of spheres, they will be called *spherical,* the same appellation applying if one of their faces is spherical and the other plane.

If the surfaces are portions of cylinders the lens is called *cylindrical* and so on. Lenses may be *sphero-cylindrical, parabolic, toroidal,* etc., according to the form of their bounding surfaces.

Let us consider a lens whose surfaces are portions of spheres, having the same radius



Principal Section of Spherical convergent lens

Let C and C′ be the centers of two circles intersecting each other so that only the shaded portion is the resultant.

The figure represents then, a section of the lens. The shaded area indicates the body of the lens itself. The full lines marking its boundaries and the dotted lines indicating the section of the remaining portions of the two sections of the spheres.

The line A B drawn through the two centers is called the *principal axis,* the points V and V′ are called the *vertices* of the surfaces, the diameter D D′ is called the *aperture* of the lens and a section of the lens through the principal axis is termed a *principal section.*

Let us now consider the behavior of a ray of monochromatic light incident upon any point of the surface of the lens which we shall suppose to be made of glass, index, 1.5 and to be surrounded by air.

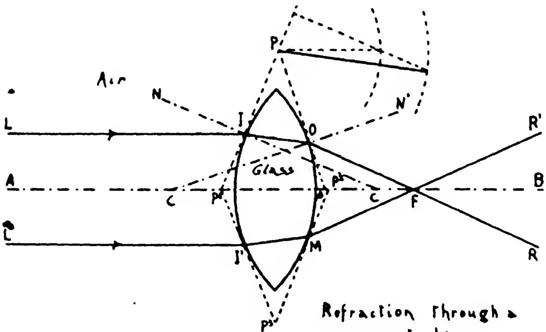
As we have seen, while considering the refraction of a ray of light incident upon a curved surface, the point of incidence may be considered as pertaining to a plane, tangent to the sur-

face of the sphere at that point and consequently normal to the radius of the sphere, and that this plane can be considered as the bounding surface of a medium of the same structure as the medium of the sphere.

Let the incident ray be the ray L I in the figure and let it strike the first surface of the lens at the point I. The ***normal*** to the surface at this point is the perpendicular to the ***tangent*** P P^2 which touches the first surface at the point I, and is represented in the figure by the line C N. We can now geometrically trace the path of the ray refracted within the lens, which is represented by the lir I O in the figure.

Now if we trace a tangent to the second surface of the lens at the point O, and if we bear in mind that the ray is now refracted from a denser medium into a rarer one, we can proceed to geometrically construct the path of the ray at its emergence from the lens.

It is evident from the figure that the emergent ray shall



Refraction through a convergent lens

meet the ***axis*** of the lens at a certain point, which will be determined by the ***curvature of the surfaces*** of the lens and by the ***composition*** or ***n*** (Index of Refraction) value of the lens itself.

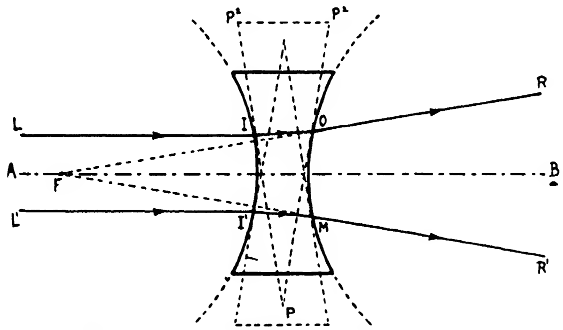
If we consider now another ray L′ I′ incident to the first surface ***below*** the axis and we follow the same geometrical construction as for the ray L I, we find that the two rays emerging from the lens after refraction converge to a common point, F, on the axis A B.

A lens which converges the refracted rays towards the axis is called a *convergent lens.*

If we now examine the figure we notice that the triangle P′ P *p* may be considered as the section of a prism made of the same refracting substance as the lens is made.

The slight inclination of the triangle is due to the different position of the points I and O in regards to the two surfaces of the lens, but if we disregard this as shown in the triangle constructed below the axis and we select the tangent point to the second surface of the lens on the prolongation of the line L′ I, we find an isosceles triangle P^1 P^3 P^2 whose base is on the axis of the lens.

. It is evident that there can be conceived as many prism sections as there are corresponding points on the two surfaces



Refraction through a divergent lens

of the lens and that these prism sections are all paired by a common base.

Let us consider now a lens, whose first face is presenting a hollow to the incident light.

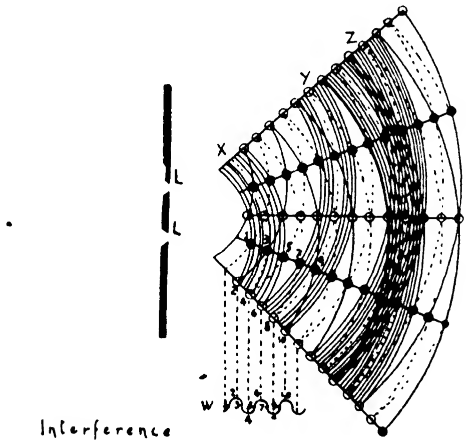
By following a similar geometrical construction as the one used for constructing the rays refracted by a convergent lens, the same innumerable series of imaginary sections of paired prisms can be visualized: These prisms do not have a common base but are inverted and therefore the rays emergent from the lens, after refraction, diverge from the axis but in such direction that their imaginary prolongation meet

at the point F on the axis and *in front* of the lens.

A lens which diverges the refracted rays is called a *divergent lens.*

Interference of Light

When two systems of light waves are propagated from two light point sources, placed in very close proximity of each other, a reciprocal action is exerted by the waves upon each other and if both sources of light are of exactly the same quality as wave length (monochromatic) this action results in alternate light and dark bands, which can be collected upon a screen.



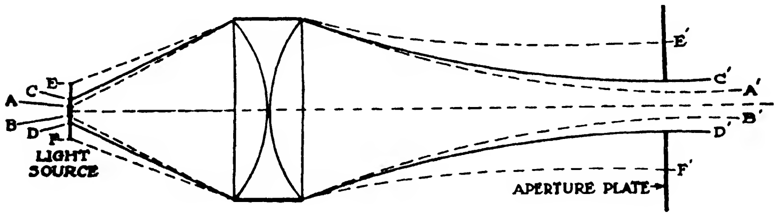
Interference

Let L and L′ be two minute openings through which monochromatic light is transmitted so that they can be considered as two point source of light, very close to each other and each propagating according to the undulatory theory their particular system of light waves. Let the full lines of the figure indicate the wave crests and the dotted lines the troughs as illustrated in the figure at W. The curved lines bounding the shaded band X will then represent the position of two wave fronts propagated from L′ including a whole wave length, while the shaded band Y will represent the same section for

wave fronts propagated from L. The shaded area Z represents then the mingling of the systems of waves emanated by the two luminous points simultaneously.

The full lines in the figure represent the crests of the waves while the dotted lines represent the troughs and therefore the distances between two full lines or two dotted lines represent a *whole wave length* and the distances between full and dotted lines represent a *half wave length.*

If one of the sources of light is covered a uniform field of light will be seen on a screen placed at some distance from the source of light, but if the two sources are permitted to mingle their wave systems, as indicated in the figure, it will be noticed that *at every point corresponding to the junction*



of two wave crests or two wave troughs the illumination of the screen will be increased and total darkness will appear at each point where a crest and a trough meet.

In the figure the small circles indicate the point of junction of two crests or two troughs and the dots indicate the points of junction of crests and troughs.

To express it in other words, there will be increase of illumination wherever the two meeting waves are in the same phase and darkness will occur whenever the two waves are in opposite phase.

If we consider the transversal motion of the waves we see that the increase of illumination takes place whenever the waves are moving in the same direction and that the light is extinguished whenever they neutralize each other by moving in opposite direction.

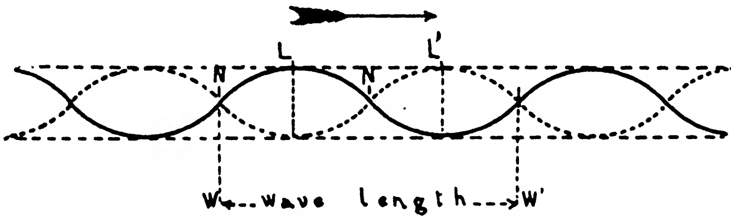
This phenomenom may perhaps be best understood by

creating interference between waves on the surface of water. If two points of disturbance are created on the surface of stagnant water it will be seen that each one of the points creates its own system of waves which, as we know, travel in the same manner as the light waves in the ether. When the systems of water waves meet it will be observed that they do not change their course and the series of concentric circles, having as centers their particular point of disturbance, may be clearly seen, the only action that takes place being a change in amplitude of the waves in some points of the combined wave fronts and extinction of the wave in other alternate points.

The explanation of the phenomenom is given by the formation of *loops* and *nodes.*

Let the undulations produced by a ray of one of the two sources of light be represented by the full line, and let the dotted line represent the undulations propagated by a ray of the other source.

Let us keep present to our mind that these undulations are *transversal.* If the light waves are propagated in such manner that one retards of *half wave length* on the other, a



Loops and Nodes

series of ventral points or *loops* L and a series of nodes N will be formed.

Within the same wave length W W′, the points L and L will be in the *same phase* and the amplitude of vibration will be increased when they meet resulting in an increase of light energy, while at the points N the waves being in *opposite phase* will neutralize each other and darkness will result.

The maximum of light energy created at the point L will

gradually decrease until darkness results at N from whence it will again gradually increase to a maximum at L′.

No loss of the total light energy emitted by the two sources of light is suffered through the phenomenom of interference, therefore, the increase of illumination at the bright bands is quadrupled.

It is evident that the alternation of bright and dark bands corresponds to each half wave length. The maxima are obtained at *even numbers of half wave length* and the minima at *odd numbers of half wave length.*

Light of any color, providing it is monochromatic, produces the same phenomenom, but *the distance between the dark and bright bands vary according to the wave length of the light, i.e., according to its color.*

The phenomenom of interference was first noticed by Grimaldi in the Seventeenth Century, and it was investigated by Young in 1802 and thoroughly explained by Fresnel in 1818 as the most conclusive argument in favor of the undulatory theory of light.

HETEROGENEOUS LIGHT

In the description of the most common phenomena of light given in the preceding chapter, only homogeneous light has been considered.

In nature, light as it is commonly known, does not present such characteristics; in other words, it does not consist of elements of an identical nature, but to the contrary, it is of a very composite nature.

If a small orfice is drilled in a wall of a dark chamber so that a small pencil of solar light is admitted through it and if this pencil of light is made to impinge upon one face of a glass prism, it will be seen that the incident light is decomposed in a great number of other lights of each one of which possesses its own particular characteristic which is called *color.*

Let L be the small opening which can be considered as a point-source of light and let it be incident upon the face A B of the glass prism A B C placed so that it produces the minimum deviation, at the point I.

The ray is refracted by the prism, but instead of emerging from it as a single ray of solar light it emerges as a beam of light composed of an innumerable number of rays of a different color.

If a screen S is placed so as to collect the emergent rays a line of varied colored lights will be seen instead of a simple image of the single point-source of solar light.

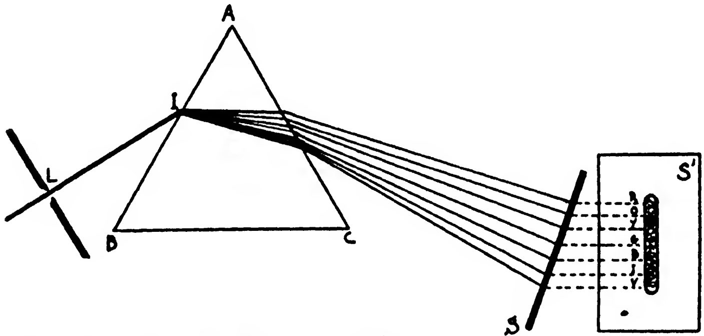
Solar Spectrum

This brilliantly colored line is called the *solar spectrum.*

Even under superficial observation it will be noticed that the range of colors varies from *Violet* at one end to *Red* at the opposite end and that the former suffers a greater deviation than the latter.

This line of colors will never present to the eye a well defined area of a single color, but all the colors will be seen to be most harmoniously blending into each other.

Some of the colors are nevertheless more prominent than others and seven of them have been selected as the most discernible and called the *fundamental colors* of the spectrum.



Decomposition of solar light

These fundamentals appear in the following order: *Violet, Indigo, Blue, Green, Yellow, Orange,* and *Red.* Besides these seven, two others, the *Blue-Green* and the *Yellow-Green,* are often referred to especially in photographic investigations.

If any one of the colors of the spectrum, the red for instance, is isolated from the others and allowed to pass through another prism, refraction will occur, but the light will *remain the same;* in other words it will not be decomposed into any other lights of different characteristics.

The colors of the spectrum are then *simple* and are said to be *monochromatic,* of one color only.

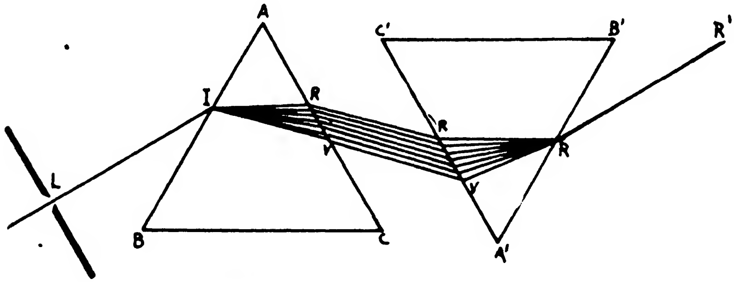
It is quite evident that if a ray of solar light is composed of a number of rays of different colors it should be possible to blend these rays together and form again a light possessing all the characteristics of color light.

Recomposition of White Light

If a solar spectrum formed by a glass prism is made to impinge upon one face of another prism made of the *same variety of glass* and placed in an inverted position in respect to the first, as shown in the figure, the recomposition of the original light is effectuated.

The incident ray of solar light, L I is decomposed by the first prism and the colored rays emerge from it forming the beam R V. At the instant that the rays of the beam strike the surface of the second prism they are all again refracted. If the second prism is equal to the first in all of its characteristics the refracted rays within the prism will all converge at the point R from which they will emerge from the prism and if collected on a screen S an image of L will be seen at the point R′.

The emergent pencil of light R R′ will be found to be in a direction parallel to the incident ray L I.



Recomposition of white light

The decomposition of the incident light may be effectuated by other means and in several other ways.

The principal colors of the spetcrum may be, for instance, collected by as many small movable mirrors and made to converge by reflection at one point. They may also be collected by means of a convergent lens which brings them at a single point on its axis.

All these experiments prove conclusively that solar light

is a composite of innumerable lights of different colors and that these different lights are *unequally refringible.* Therefore, each one of the colored lights possesses its own *index of refraction for the same refracting medium* and, consequently, all different colored rays *travel within the medium at a different velocity.*

Thus the solar spectrum proves that the violet rays, which are deflected towards the base of the prism, are more refringible than the blues, which, in turn, are more refringible than the greens and so on to the reds which mark one end of the visible solar spectrum.

THE SPECTRUM OF ARTIFICAL LIGHTS

Artificial lights are very seldom monochromatic. They can therefore be decomposed into their component lights and, although they rarely contain all of the colors of the solar spectrum, *all of their component colors are to be found in the solar spectrum.*

Thus the solar light is, so to speak, the most complete of known lights and has been used by the early experimenters almost exclusively in their investigations.

As the intensity of light produced by heat varies with the composition of the body submitted to its action and to the intensity of the heat factor, so the intensity of the colors of the spectrum of heated bodies varies according to the composition of the body and to the degree of heat energy to which it is submitted.

Thus the maximum of energy radiated by a tungsten filament will be found in the red end of the visible spectrum, while a maximum will be found in the green region of the spectrum if a filament of copper is heated to incandescence.

It is quite evident that the light characteristics of the different bodies are of extreme importance in all phases of human endeavor and most especially in all photographic procedures.

ELEMENTARY THEORY OF IMAGE FORMATION

IMAGES

WHENEVER an object is either luminous or is stricken by light emanated by a luminous body is presented to the eye the radiations that it emits as in the first case, or the ones that it reflects, as in the second case, produce the sensation of vision and the object is said to be *seen.*

When the rays emanated from the object enter the eye they suffer a series of refractions and an *image* of the object is formed upon a very sensitive membrane in the eye called the retina and is transmitted to the brain by some quite unknown physiological and psychological processes.

The image of the object is a reproduction or counter-part of the object itself, or better, a reproduction of each and every one of the points of the object from which a ray of light is emitted so it may reach the eye without encountering any obstruction in its path.

The image formed upon the retina is a purely physical one and the conditions necessary for its formation and for the formation of similar images have been known and studied for several centuries.

When an image is formed by a suitable combination of lenses so that it can be collected upon a screen, each point of the screen radiates reflected rays of light of different intensity and color, according to the rays forming the image itself, and if the eye is so placed as to receive these rays it will form on the retina a counterpart of the image and therefore a counterpart of the object itself. The impression is then the same as if the eye was looking directly at the object.

If the image is collected on the screen so as to make a permanent impression upon it, and this is indeed the case in

photography when the sensitive plate or film acts as a collecting screen, such image is revived into the eye at any time its gaze is directed upon it.

It is obvious that the image formed upon the photographic plate or film must be as similar as possible to the object photographed in order to transmit to the mind the impression that the onlooker is looking at the object itself.

The formation of such perfect image involves such optical problems and considerations which will be surveyed in the following chapters.

The preceding chapter has dealt with the principles underlying and the laws governing the propagation of light. We shall now consider how these principles and laws are applied to the formation of images suitable to photographic rendition.

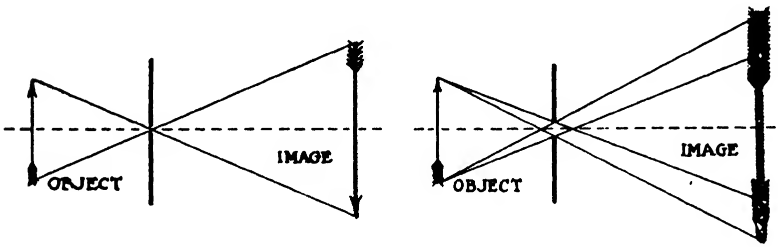


Image Formation—Light from the luminous arrow at the left passing through the pinhole forms a sharp image at any distance; that transmitted by the larger hole produces a blurred image

Pin Hole Images

It has been previously stated that an object emits very definite radiations *from each of its points* and that these radiations travel in a straight line. It was also said that the *camera obscura* is an instrument by means of which images of objects can be collected upon a screen.

The formation of images in the camera obscura is the simplest example of such phenomenon and its explanation will serve as guide in the study of image formation by optical instruments.

If we theoretically suppose the orifice of the camera obscura small enough to permit the passage of only one of the several rays of light emitted by a given point of the object we can visualize that only this one ray concurs to form the image of the object point on the wall of the camera obscura opposite to the opening and only one single ray from each point of the object will enter the camera obscura and strike the wall in such position that a complete image of the object is formed on it.

Let us consider the line L L′ as representing the object; O the small opening in a wall of a darkened room and S a screen upon which the image of the object is formed.

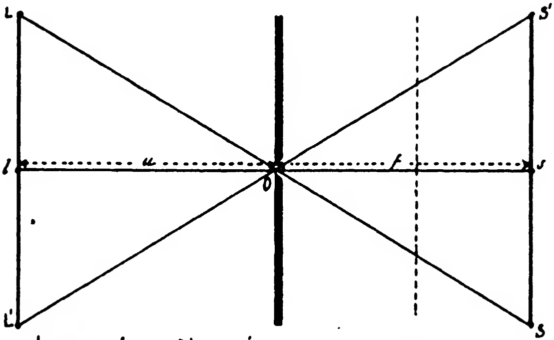


Image formation in camera obscura

The point *l* of the object emits rays in all directions but only the ray *l s* enters the instrument due to the extreme smallness of O. This ray will then impinge upon *s* on the screen and can be viewed either by reflection, by placing the eye at any place in front of the screen or by looking at it from points behind the screen if the screen is transluscent.

The ray *l s* in the figure is perpendicular to the opening and it marks the position of the imaginary line called the *Axis*. The point O on the axis becomes the meeting point of all the rays which, coming from the object are admitted through the opening into the camera obscura. Therefore, if two other object points are considered, such as L and L′ we can easily

understand that only one of the rays emitted by these points will pass through O and impinge upon the screen at the points S and S′ respectively. Every point of the object placed in front of O will then transmit one single ray through the opening and each one of them will strike the screen at a point dependent upon the inclination of the ray in respect to the axis.

Each *object point* will, therefore, have its corresponding *image point* on the screen. Two such similar points are said to be *conjugate points.*

Thus S is the conjugate of L and S′ the conjugate of L′. All points between S and S′ are conjugate to points between L and L′ and S S′ is then a perfect image of L L′.

Object and Image Size

If, while the object is kept stationary, the screen is displaced to a position nearer the opening, as illustrated in the figure by the dotted line, an image will be formed at this new position, but its size will be found to have varied.

It is evident from the figure that the closer the screen is to the opening the smaller the image and vice-versa the greater the distance of the screen from the opening the greater is the size of the image.

If the screen is kept stationary and the object is set nearer or further away from the opening, the size of the image will vary accordingly and be greater, the closer the object is to the opening.

It is quite obvious that, due to the geometrical construction of the figure some definite relation exists between the size of object and image in respect to the distance between them.

The ratio between the size of the image and that of the object is called the ***magnification*** and is denoted by the letter m.

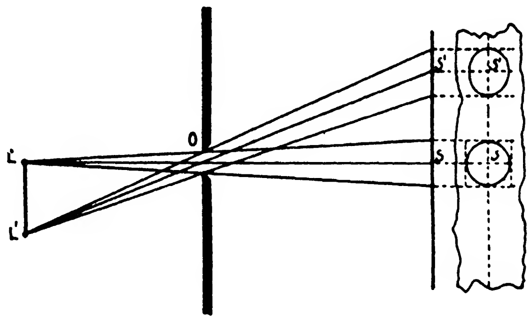
The distances from the object to the opening and from the image to the opening are measured along the axis and are respectively called the *object distance* and the *image distance,* the first being denoted by the letter u and the second by the letter f.

The Pin Hole Opening

The pin hole opening has been this far considered as small as a theoretical ray of light.

In actual practice, such smallness is unattainable so that the opening of a camera obscura always has a certain area and a bundle of rays originated by each object point will enter the camera obscura instead of the single ray previously considered.

Another factor has to be taken into consideration in the investigation of the size of the pin hole opening. It has been explained in a preceding chapter that when a pencil of light is partially intercepted by a keen edge or is made to pass through either a narrow slit or a small opening the phenomenon of *diffraction* takes place.



Sharpness of a pin hole image

If the pin hole of the camera obscura is so small that diffraction is provoked the sharpness of the image is greatly impaired. A lack of definition will also be the result from a pin hole of too great an area.

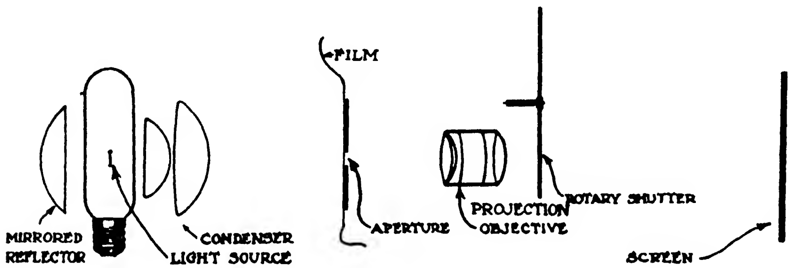
Let O be the orifice of the camera obscura, L L′ the object and S S′ its image. The pencil of rays emanated by the object point L, which may enter the orifice O, assumes a conical form and therefore, instead of producing at S the exact image of the point L it produces a circle, the size of which is dependent upon the size of the opening and the image distance. The axis indicates the path of the *principal* ray and the center

of the circle while the marginal rays will trace the circumference of the circle.

If the size of the opening is so calculated that it is as small as possible without creating a disturbing amount of diffraction this small patch of light will then represent the *best obtainable image* of the object point L.

The same reasoning applied to the object point L′ proves the formation of a patch of light at the point S′ of the screen, which is the best obtainable image of the object point L′.

The circular shape of the patch will be altered into an oval



Essential Optical Elements for Motion Picture Projection with Mazda Lamps

shape the farther the image of the object point is from the axial point S. The image of the central point will thus be sharper than at any other point of the image surface, this sharpness gradually diminishing the farther the image point is from the center S.

The patches of light thus formed are called the *circles or discs of confusion* and it is quite evident that the sharpness of the whole image is dependent upon the size of these discs.

Resolving Power of the Eye

The unavoidable formation of the discs of confusion would make it impossible to obtain images of sufficient sharpness if the eye had the power to distinguish their existence at the smaller size that diffraction permits.

But the eye does not fortunately possess such a keen

power of separation.

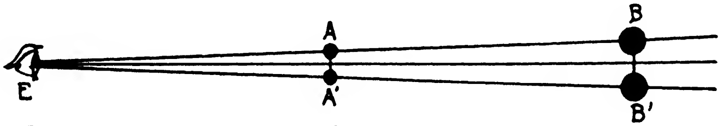
If two lines are drawn on a sheet of paper very close and parallel to each other and are looked at while the paper is moved away from the eye, a certain distance will be found at which the eye fails to distinguish any separation between them, and the two lines blend into each other and appear as one. Two points will, under the same conditions, also appear as one.

The power that the eye possesses to distinguish two separate lines or points is called the *resolving power of the eye.*

There are many factors which control the resolving power of the eye, such as the size of the two points in respect to the distance separating them, the intensity of the light under which they are viewed, the contrast existing between the points and the spaces of separation and so forth.

All these considerations waved aside it can be stated as a general and elastic rule that the eye has the power to resolve two points when these are at a distance apart which subtend a visual angle greater than one second or 1/60 of a degree.

Suppose the two points placed at A and A′ to be at such a distance from the eye E that the angle A E A′ is the resolving angle. The two points B and B′ set at a greater distance from the eye, must be further apart from each other to be still distinguished by the eye as two separate points.



Resolving power of the eye.

Several practical experiments will demonstrate the phenomenon.

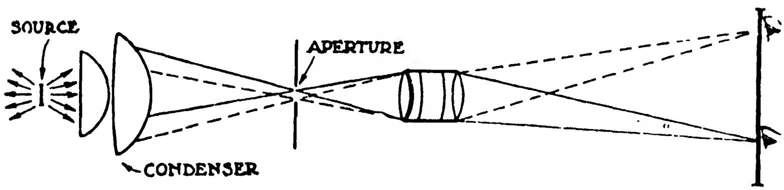
Suppose a street lined on one side by a series of brick buildings. If we look up the street we clearly distinguish on the nearby buildings the lines of separations of the bricks,

especially if these are held together by white mortar. The further the buildings are from the eye the more difficult it is to distinguish the separation and at a certain distance the walls of the buildings will appear of a uniform red hue.

Leaves of trees are perfectly discernable from a certain distance but such distance can be found at which the whole tree will appear as a mass of green and the leaves will no longer be distinguishable.

A roughly plastered wall will appear as a smooth surface if looked at from a certain distance and so forth. Many examples can be cited even to those involving such great distances as the interplanetary ones.

Two stars, for instance, may be at a tremendous distance from each other and yet will appear to the naked eye as a single luminous point. The plurality of stars can only be determined by the use of powerful telescopes.



Although the distance between two stars may be several millions of miles the still more enormous distance at which they are from the Earth makes their separation to be within the angular limit at which the eye loses its resolving power.

It results that if the discs of confusion which concur to form an image are sufficiently small so that they do not impair the fine details of the subject enough for the eye to resolve such impairment, the lack of definition which is caused by the discs will not be detected by the eye and the image will appear *sharp*.

The circles of confusion are not separated from each other but overlap throughout the whole image surface and therefore it is seldom, if ever, necessary to have recourse to the very smallest obtainable disc of confusion for obtaining a so-called perfectly sharp image.

IMAGE FORMATION BY PLANE MIRRORS

A MIRROR is a surface possessing a high reflecting power. The rays of light emitted from an object placed in front of a mirror are reflected by its surface, following the laws of reflection, and the eye placed in front of the mirror in any position will receive these rays which, reflected by the surface, will enter its pupil.

The eye will then see an image of the object as if the rays were coming from behind the mirror.

The part of the science of optics which deals with the phenomena of reflection and which deals especially with the formation of images by mirrors is called *catoptrics,* and an instrument which forms images by reflection is called a *catoptric instrument.*

It is evident from the figure that the image of any and all points of the object is seen in the direction of the imaginary prolongation of the reflected rays at a distance equal to that of the given points so that it will appear of *equal size as the object,* it will be *erect* but *reversed as to sides.*

Such an image has *no real existence.* The rays do not come from behind the mirror and cannot therefore be collected upon a screen. The real image which provokes the visual stimulus in the brain is formed by the optical system of the eye, the position of the image formed by the mirror being only an impression having no real existence. Such an image is called *virtual.* Any virtual image can be made to form a *Real* one by a suitable refraction through a convergent optical system as in the case of the eye above referred to.

It is quite appropriate to make here a distinction between the true meaning of the word mirror and the same word as

applied to describe the well known object of everyday use.

A mirror, in optics, is a smooth and highly polished *surface* reflecting a great amount of the rays of light impinging upon it. A glass mirror is in fact composed of a mirror and a support, the mirror being the silver or mercury surface and the glass acting as support and protection to the mirror itself.

A glass mirror has two reflecting surfaces, the front face of the glass plate and the silver or mercury coating on the opposite face.

If a lighted match is placed in front of a glass mirror and

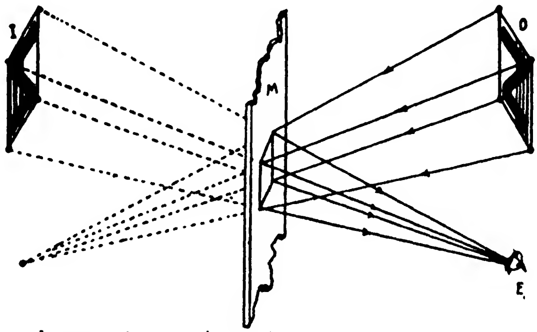


Image formation by a plane mirror

is looked at obliquely two very distinct images of the match will be seen. One of the two images is formed by reflection from the silver coating and is the brightest of the two, the other is formed by the reflection of the surface of the glass.

Furthermore these two images act as luminous objects in respect to either one of the two reflecting surfaces and other images of the match are to be seen which would multiply to an infinite number were it not for the absorption and scattering of the certain portion of the light which takes place at each reflection.

Formation of Multiple Images by Two Plane Mirrors

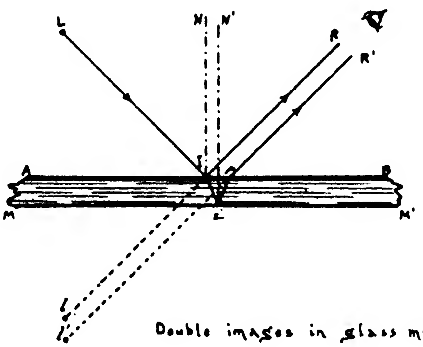
If an object is placed between two plane mirrors so set that they make an angle with each other, several images are

to be seen by reflection and the number of images varies according to the angle at which the mirrors are set.

It is easy by the figure to follow the path of the rays reflected by the two surfaces and finally reaching the eye.

The multiple virtual images thus formed are apparently situated upon a circumference having for center the point of junction of the two mirrors and a radius equal to the distance from this point to the object or luminous point source of light. If the two mirrors are set at right angles, three images are to be seen; if the mirrors are set at an angle of 60 degrees, five images are produced and seven images are formed by two mirrors set at an angle of 45 degrees.

The smaller the angle, the greater is the number of images so that if the two plane mirrors are set in a position parallel to each other and an object or luminous point is set between them, the number of reflections which takes place from one mirror to another and therefore the number of images, is



Double images in glass mirror

theoretically infinite. The final disappearance of any visible image is due to the absorption and scattering of light characteristic to the reflecting material.

When the image of a stationary object is formed by a plane mirror and the mirror is turned around a certain angle by rotating it about a vertical axis, the apparent displacement of the image will be double the displacement by rotation.

MIRRORS WITH CURVED SURFACES

A mirror may, of course have a surface of a shape other than plane. According to their shape mirrors are called *spherical; cylindrical conical,* etc., and are defined as *convex* or *concave* according as their surface is respectively a bulging or a hollow portion of a sphere, a cyclinder or a cone, etc.

Since we are concerned only with the formation of images possessing as close a relation as possible with the object we will concern ourselves only with symmetrical surfaces and disregard those surfaces which although symmetrical give a distorted image, such as cylindrical and conical surfaces.

We have seen that the determination of the image of an object is obtained by the determination of the images of its component points.

Since three points which represent the three vertices of a triangle are sufficient to completely define the position that a surface occupies in space it is quite evident that the finding of three image points corresponding to one object surface, placed perpendicularly to the axis of the instrument forming the image, will completely determine the position of the image of such object.

Since in the figures which illustrate the description of image formation only a section of the optical instrument is shown, it follows that the position of only two image points will be determined, the third being considered to be outside the plane of the paper.

In the elementary investigation which we will make on the formation of images by curved reflecting surfaces we shall consider only rays of *monochromatic light* and only such rays that lie very near to the axis of the reflecting surface and are thus comprised within a very small region surrounding the axis itself. Rays lying within this region and inclined in regard to the axis will then make extremely small angles with it.

This limitation is necessary for the fact that rays lying at a certain distance from the axis or inclined to it at a greater angle produce images presenting imperfections of such charac-

ter that they would render difficult and confusing the explanation of the elementary theory of image formation.

The rays which are limited within the narrow axial region previously referred to are called *paraxial rays*.

Since it would be impossible to clearly illustrate only paraxial rays in the drawings pertaining to this and some of the following chapters the light rays in the figures will be traced at a greater distance and with a greater inclination toward the axis than the supposition comports.

The drawings will then distort and misrepresent the relations existing between distances and size of angle but will nevertheless serve as guide to the comprehension of the path followed by the light rays in the formation of images.

Focal Point in Spherical Convex Mirrors

The figure represents the section of a spherical convex mirror whose center of curvature is at C.

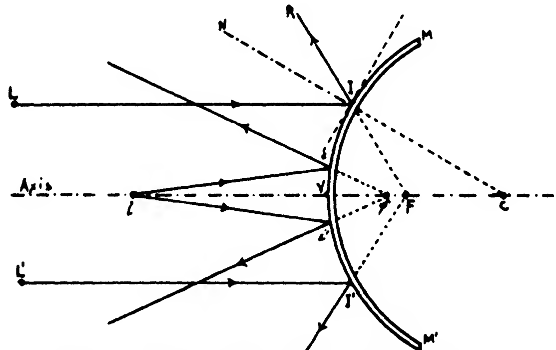


Image Focal points in a spherical convex mirror

Let M M′ be the mirror and let the ray L I, parallel to the axis strike the reflecting surface at I.

The point I may be considered as a point of a plane surface tangent to the surface of the mirror at the point I and possessing all its reflecting properties.

The incident ray L I will be reflected so that it makes with the normal to this imaginary plane surface an angle of

reflection equal to the angle of incidence and thus follow the direction I R.

The imaginary prolongation of the reflected ray *behind the mirror* will cross the axis at the point F.

Another parallel ray L′ I′, below the axis, will also be reflected by the mirror in such direction that its prolongation will meet the axis at the same point F, which is found to lie very near the middle of the distance between the center of curvature C and the vertex of the mirror V.

All paraxial rays parallel to the axis will be reflected by the mirror in such direction that their prolongations meet at the point F which is called the *principal virtual focus* of the mirror. Virtual, because the light rays do not actually meet there and therefore it has *no real existence.*

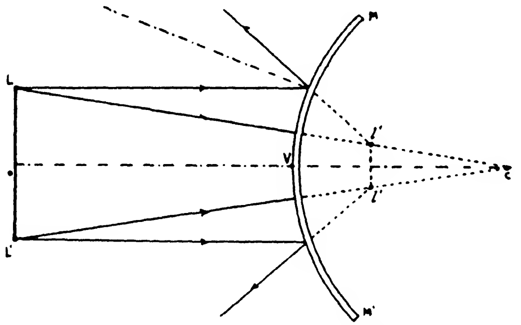
Let us consider now a luminous point placed on the axis at a *finite distance* from the mirror and let this point be designated by the letter *l*. Two of the paraxial rays emitted by *l*, for example the rays *l i* and *l i′*, will be reflected by the mirror in such direction that the prolongation of the reflected rays will meet at a point *f* behind the mirror and nearer the mirror than F. All rays within the paraxial region emitted by *l* and incident upon the reflecting surface will be reflected so their prolongations all meet at the point *f* which is then the virtual focal point of the mirror for the rays emitted by *l*. In distinction to the principal focus, this point is called the *conjugate focal point* of *l* and marks the position of its virtual image.

It is quite evident that conjugate foci may be determined for object points placed on or outside the axis and at any distance from the reflecting surface, each of these conjugate foci occupying a position in relation with the position of the point in the object space. Only rays parallel to the axis, which can, therefore, be considered as coming from a luminous object placed at an *infinite distance* from the mirror, form a *focus* at F and the distance F V is then *constant* for the same mirror and for all rays coming from an object placed at infinity. The distance F V is called the *focal distance* of the mirror.

Thus the expression *focus* of a mirror and in fact, of all other image-forming optical instruments applies only to such point situated on the principal axis of the instrument, which is formed by the meeting, after reflection or refraction, of the paraxial rays proceeding from an object placed at such distance from the instrument that its rays follow a path which can be considered parallel to its axis.

The rays of the Sun, for example, incident upon the paraxial region of a convex mirror are considered to answer this condition of parallelism.

The light rays emitted by an object which is placed perpendicularly to the axis and at some distance from a spherical convex mirror will be reflected by the surface of the mirror as illustrated



Virtual image by spherical convex mirror

FOCAL POINTS IN A SPHERICAL CONCAVE MIRROR

In a concave mirror the incident rays parallel to the axis will be so reflected that they actually meet at a point situated on the axis and *in front* of the mirror.

The same reasoning, which has been a guide in the explanation of the formation of the focal point in the case of spherical convex mirrors, will permit to follow the path of the rays which are reflected by a spherical concave mirror.

The paraxial rays parallel to the axis are so reflected, as shown in the figure, that they converge to the ***real principal focus*** of the mirror at F and the oblique rays from an object

point, such as the rays $l\ i$ and $l\ i'$, will converge after reflection at the *conjugate focal point f.*

These focal points are *real* because the reflected rays actually concur to form them and it is possible therefore to collect them upon a screen. A real image of an object can therefore be obtained from a concave mirror.

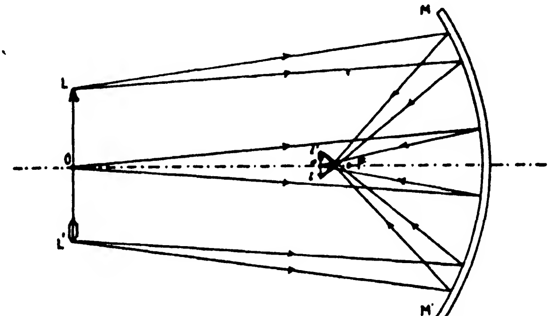


Image formation by spherical concave mirror.

Let L L′ represent an object surface perpendicular to the axis of the mirror. The path of two rays which are emitted by the point L of the object and reflected by the mirror converge as shown in the figure to a point *l* which is therefore the conjugate focal point of L.

Similarly two rays from L′ will be so reflected by the mirror that they meet at the point l′, conjugate focal point of L′ and two rays from the object point O on the axis will converge, after reflection, at the point *o* also situated on the axis of the mirror.

From any point of the object a pair of rays can be traced incident upon any point of the reflecting surface which will, after reflection, converge to a conjugate focal point between l and l′.

Since every object point from L to L′ will have a conjugate between l and l′ and since the reflected rays *actually meet* to form these conjugate points, the image l l′ of the object L L′ is *real* and can be collected upon a screen placed perpendicularly to the axis at the point *o*. If the screen is a photographic

plate or film a reproduction of L L′ may be collected and fixed so as to obtain a permanent image of L L′.

The construction of the figure proves that such an image is *real, inverted, smaller than the object and situated between the center of curvature of the mirror and its principal focal point.*

Due to the reversibility of the path of the light rays, if we suppose *l l′* to represent the object, its image will be formed at L L′ and it will be a *real, inverted* image and *its magnification will be the greater as the object is nearer the principal focal point of the mirror.*

If the object should be placed at the focus of the mirror no image would be formed because the reflected rays would follow a path parallel to the axis and, therefore, they would never meet to form any, either real nor virtual foci.

The magnitude of the images formed by spherical mirrors is dependent upon the curvature of the mirror, in other words upon the length of the radius of the sphere of which the mirror is part.

Spherical Aberration by Reflection

The want of correctness of the figures illustrating the formation of images is due to the already expressed consideration concerning the paraxial rays and by the fact that rays outside the paraxial region do not actually meet at the principal focal point of a spherical mirror.

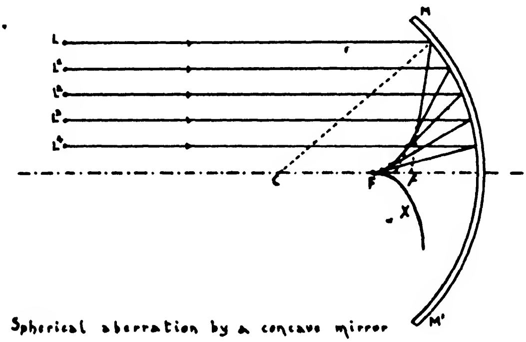
The rays parallel to the axis and incident upon reflecting surface of a convex mirror, at some distance from the axis will meet it at a point nearer the mirror than the principal focal point.

This inability to bring all of the incident rays to a common focus is cause of a lack of sharpness of the image for the rays outside the paraxial region. This lack of sharpness gradually increases the farther the incident rays are distant from the axis, and thus the image formed by a spherical mirror will present a sharp center and will gradually diminish in sharpness towards its periphery.

The effect is detrimental to the true reproduction of the

object. All imperfections provoked by image forming instruments which, therefore, result in a deviation from the true rendition of the appearance of the object itself, are called *aberrations.*

Since the spherical shape of the mirrors is the cause of the want of trueness in images formed by reflection from such mirrors this aberration is called the *Spherical aberration by reflection.*



Spherical aberration by a concave mirror

PARABOLIC MIRRORS

Since the spherical aberration is the resultant of the shape of the mirror, it is possible to conceive reflecting surface of such form that it will reflect all incident rays traveling in a direction parallel to the axis, to one single point on the axis itself.

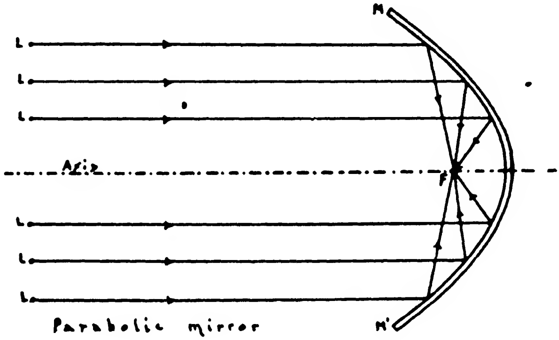
A *parabolic* surface answers to this requirement.

Parabolic mirrors are concave mirrors whose surface is generated by the revolution of a parabola about its axis. A parabola is the curved line obtained by intersecting a cone with a plane parallel to one of its sides.

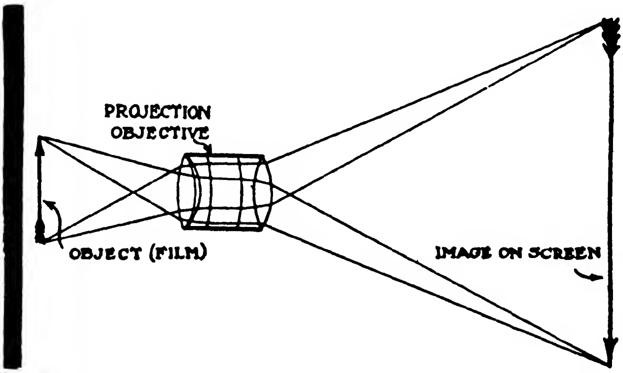
Since in parabolic mirrors the reflected rays converge all to the principal focal point, it results obviously that, due to the reversibility of the light path, if a luminous point is placed at the focus of such mirror, its rays will be reflected in a direction parallel to the axis and maintain a greater intensity than the rays which are diverged from this parallelism by a

spherical mirror.

Parabolic mirrors will therefore be found very convenient when used as reflectors and although more difficult to construct than spherical mirrors they are extensively used whenever a great intensity of the reflected light is required.



The reflectors of locomotive and automobile headlights, the light beacons used in landing fields for aeroplanes and some of the reflectors applied to light units used in making and showing of motion pictures are designed upon this principle.



The Projection Lens—Light Reaching any Part of the Lens from a Single Point on the Arrow is Focused at only One Point on the Screen

VIRTUAL AND REAL IMAGES

THE virtual images formed by mirrors for the very fact that they cannot be collected upon a screen, cannot provoke the chemical changes in the photographic emulsion which are the cause of the permanent photographic image.

The real images formed by mirrors are used in photographic procedure only in special cases which lie far beyond the scope of this book and have not found as yet adaptation in practical motion picture work.

The image formed by the camera obscura, is a real image because each small pencil of rays which is admitted through the pin hole opening, actually strikes the surface of the screen. If the screen is a sensitive plate or film, it will be affected by these pencils of light and the photographic permanent image of each and every point of the object may be obtained.

The image formed by the camera obscura it has been said to have such a low luminosity that a great amount of exposure is necessary for the sensitive emulsion to undergo the changes necessary to produce the photographic image.

The limitations imposed by the lack of sufficient illumination of the image obtained by a pin hole are overcome by the possibility of *converging to one point in an image plane situated behind the optical system, a great number of rays emitted by one object point.*

The figure illustrates the condition of converegnce which the light rays shall answer to bring forth the increase of illumination of image-points which is highly desirable.

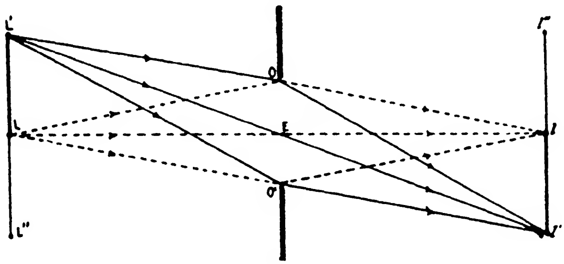
The aperture O O′ which admits the light rays, being greatly enlarged, it results that the great number of rays emanated from an object point L for example, and made to pass through the aperture would not form an image unless they are made to converge so that their path are directed

towards one single point in the image space and form there a conjugate focal point of the object point L.

This effect is obtained through the phenomenon of refraction and by the use of convergent lenses or systems of lenses.

A lens is a piece of refracting material most usually glass, by which the path of the light rays may be controlled by means of both the quality of the material of which the lens is made and the shape of the refracting surfaces which serve as the boundary of the lens.

That part of the science of optics which deals with refracting instruments is called the *dioptrics* and therefore all instru-



Convergence of light rays concurring to form an image

ments which form images through refraction are called *dioptric instrument.*

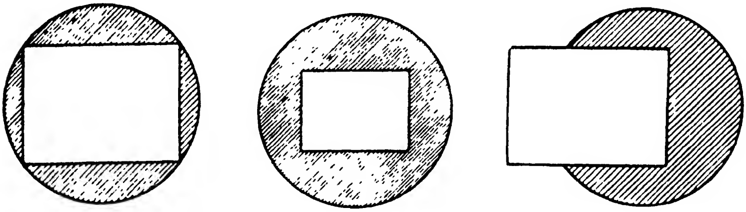
In a preceding chapter the path of a ray of monochromatic light through a convergent lens has been demonstrated.

By tracing the path of at least two of the rays emitted by an object point situated either on the axis of the lens or out- of it and passing through the refracting system, we should, n order to obtain a perfect image of the object point, find them to converge at exactly the same point in the image space where a conjugate of the object point would therefore be formed. In other words a perfect image of that object point should be formed by the meeting of the refracted rays and such image would be much more luminous than the image of the same point of the same object obtained through a pin hole, because of the concentration of a great number of light rays instead of the direct effect produced by the rays of the extremely small pencil of light limited by the size of the pin

hole.

This would be the ideal condition under which an object, occupying one plane perpendicular to the axis of the lens, would be reproduced in an image plane. In reality many factors enter into play, which concur to diminish the trueness of rendition of such image.

Before entering into the analysis of the deficiencies found in the image formation by lenses it is necessary to obtain a good comprehension of the principles underlying such image formation and of the nomenclature used to designate the different points distances, angles, and effects pertaining to this phenomenon.



A B C.

In the motion picture projector, a round spot of light is projected from the condenser lens upon the aperture plate, which has an opening with a height equal to ¾ of the width. It is clear that the maximum amount of light will be allowed to pass when the diameter of the spot equals the diagonal of the aperture, as shown in A. When the light source is ahead or behind the focal point, and the beam is spread.

Also, when the light source is at the left of the focal point, the beam is projected to the right of the aperture (C); and the converse is also true. In both of these positions, light is wasted.

In order to render the demonstration of such phenomena less difficult for the beginner we shall confine ourselves to the geometrical survey of the path of the rays and disregard the trigonometric computations involved in the designing of lens systems.

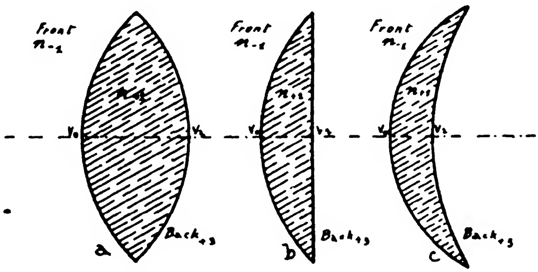
We shall also, as in the case of the formation of images by mirrors and for the same reason consider at first only paraxial rays of monochromatic light though again in the drawings the magnitude of the angles will be greatly exaggerated.

Positive Convergent Lenses

Three distinct kinds of positive convergent lenses may be defined according to the form characteristic of the lens.

The most distinct characteristic of convergent lenses is that they are *thicker at the axis than at their edges.* Recalling the path followed by rays refracted in convergent lenses this characteristic proves to be essential to provoke the convergence of the refracted rays.

Lens a is called *biconvex* because both of its surfaces are convex or bulging outwards. The radii of curvature of the lens illustrated in the figure are equal for both faces of the lens but it is quite evident that the surface of a biconvex lens



Positive convergent lenses

may have radii of curvature varying in length. An infinite variety of such lenses may therefore be designed each one of which will have its proper power of convergence.

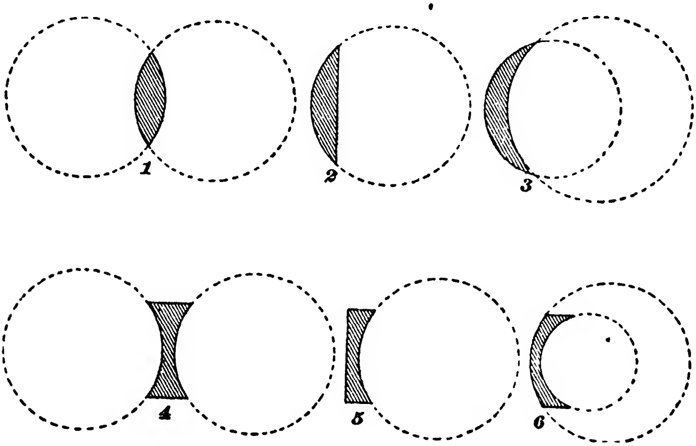
Lens b is called a *plano-convex* lens because one of its faces is convex while the other is a plane perpendicular to the axis. The plane surface may be considered as a portion of a sphere having a radius of an *infinite* length while the other face may have a radius of any desired *finite* length.

Lens c is called a *convergent meniscus* because of its *crescent-shaped form.* Again the radii of curvature of the two faces may be equal to each other or vary in length at the will of the designer.

Since the investigation of the path of the light rays through the different media is fundamental in the designing of optical

instruments and, therefore, essential for the understanding of their functions, it has been found necessary and convenient to establish a notation with reference to the points, angles, surfaces and distances whose determination is essential for the calculation of the path of the rays which concur to form the image.

Conventional symbols and signs have been adopted some of them internationally used, such as the symbol F to denote the principal focal point and the signs + and — to indicate the positive or negative characteristics of the values under



consideration; other symbols and signs have obtained a less international recognition and are indiscriminately used by the different investigators.

The use of special notations not only serve to simplify the expression of formulae, but also to condense, so to speak, the expressions to be used in the explanation of the phenomena pertaining to the image formation by optical instruments. Optical symbols and signs may, therefore, be considered as the stenographic language of the science of Optics.

To quote Dr. Steinheil: "The point of intersection of the first refracting surface with the axis is the origin from which the reckoning is commenced.

"Media are denoted by odd numbers; surfaces of separa-

tion are denoted by even numbers.

"*Constants* are indicated by *small italic* letters.

"The numerical suffixes at the right lower side of the letters indicate the medium to which the constant refers.

"The suffixes are preceded by the signs plus (+) or minus (—) according as they are at the right or the left of the point from which the reckoning commences."

Thus in the figures where the lenses are considered as being surrounded by the medium air:

n represent the constant "Index of refraction."

n_{-1} indicates the index of refraction of the medium *in front of* the first face of the lens.

V_0 indicates the *vertex* of the lens, or point of intersection of the first surface of the lens with the axis. Considering the light ray to travel from left to right, V_0 is also the origin from which the reckoning is commenced.

n_{+1} indicates the *index of refraction* of the lens.

V_2 indicates the *vertex* of the second surface of the lens.

n_{+3} indicates the index of refraction of the medium into which the refracted ray emerges from the lens.

In the case above outlined, the first face of the lens is supposed to be turned towards the object and the light rays emanated from it, are therefore supposed to travel from left to right.

Negative Divergent Lenses

Although divergent lenses do not form real images and are, therefore, unsuitable for photographic purposes if used alone, they play an essential role in combination with positive lenses as it will be seen later.

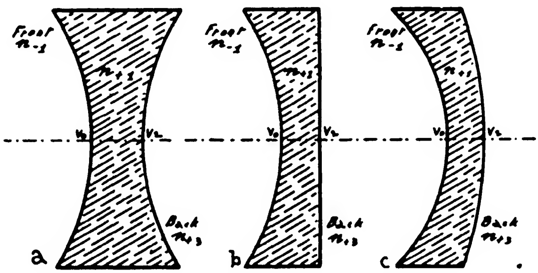
As in the case of convergent lenses, three distinct kinds of divergent lenses may be defined according to the different combinations which can be obtained with hollow curved surfaces.

The main characteristic of divergent lenses is that ***they are thinner at their centers along the axis than at their edges,*** in opposition to convergent lenses the characteristics of which

are diametrically opposite as has been shown.

Lens a is called *biconcave* because both of its faces are concave, that is they are both part of hollow spheres. The radii of curvature of the two faces may be equal in length or they may be of different magnitude and it is then evident that by varying the radii of curvature the power of divergence of the lens may be controlled at will.

Lens b is called a *plano-concave* lens, one of its faces being concave and its radius having any desired *finite* length while the other face is a plane and can, of course, be considered as a curved surface having a radius of *infinite length.*



Negative divergent lenses

Lens c is called a *divergent meniscus* because of its similarity to the crescent shaped moon. Its faces are both curved surfaces and may have any desirable *finite* radius of curvature.

The same notations used in connection with convergent lenses apply to divergent ones and the symbols and signs in the figure do not require any further explanations.

Focal Point of Lenses

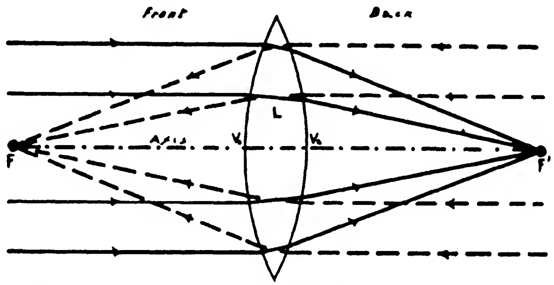
The points to which converge the luminous rays emanated by a single object-point after refraction through a convergent lens and the points created by the imaginary prolongation of the rays refracted by a divergent lens are called the *foci* of the lens.

As in the case of mirrors, *principal* and *conjugate foci* are

formed according as the paraxial rays emanated by the object are parallel to the axis or inclined to it.

Paraxial rays parallel to the axis may be incident upon a lens striking either one or the other of its two surfaces. In both cases, one particular ray will always be found which coincides with the axis and which will be transmitted through the lens without suffering refraction.

All other paraxial rays parallel to this *principal ray* and traveling from left to right (traced as full lines in the figure)



Real principal foci in convergent lens

will be so refracted by the lens that they will meet at a point F′ of the axis which is called the *second principal focal point* of the lens and which lies behind the lens itself.

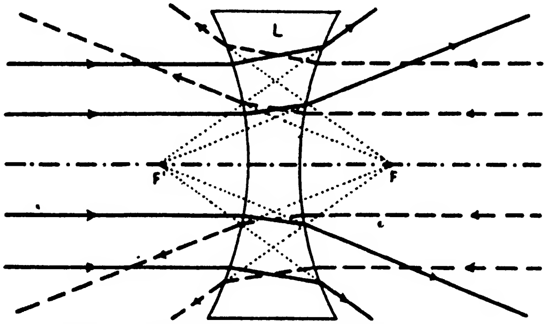
Vice-versa, paraxial rays parallel to the axis proceeding in a direction from right to left (traced as broken lines in the figure) will, after refraction, meet at a point on the axis *in front* of the lens and form the *real first principal focal point* of the lens which is designated by the letter F.

Although the lens chosen in the figure for the demonstration of the formation of the focal points is a *biconvex* it is quite evident that a similar construction will determine the foci of plano-convex lenses and convergent menisci.

Concave or divergent lenses, as divergent mirrors do not form real foci and these points are virtually located at the meeting of the prolongation of the refracted rays.

As in the case of convergent lenses the principal foci of

divergent lenses are formed by the refraction of the paraxial rays parallel to the axis.



Virtual principal foci in a divergent lens

From the figure it is easily deduced that the *virtual second focal point* in the case of divergent lenses is located *in front* of the lens at F′ and the *virtual first focal* point of the lens is to be found *behind* the lens at F.

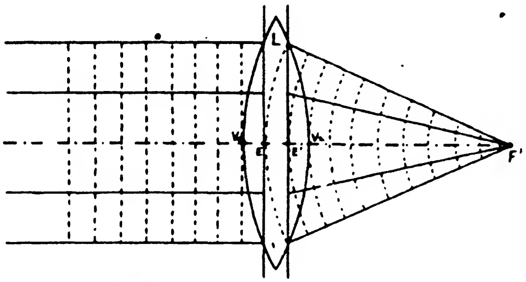
It is quite evident that the conjugate foci of paraxial object points situated either on or outside the axis and at a *finite distance* from the lens may be found by similar constructions as the ones used for the locating of the principal foci.

The Diopter

The formation of the principal foci by a lens, be it convergent or divergent, is the resultant of the characteristics of the lens called the index of refraction and of the curvatures of its faces. This effect can be expressed as the particular power of the lens to impart to the incident rays a certain amount of convergence or divergence.

It has been explained that the propagation of light takes place in the form of spherical waves. Spherical waves proceeding from an infinite distance have a radius of such length that the wave front reaching the lens may be considered a plane. As soon as such plane wave front reaches the first

surface of a lens each point of this surface becomes a center of disturbance and the refracted rays in their new path of propagation form a wave front which has a curvature dependent upon the power of the lens. This power will be *positive* for convergent lenses and *negative* for divergent ones and thereby convergent lenses are called positive and designated by the sign plus (+) while divergent lenses are called negative and are designated by the sign minus (—).



Power of convergence of a positive lens

A system of numbering lenses according to their power of convergence or divergence has been adopted by International agreement and the chosen unit of measurement has been called the *Diopter.*

The *diopter* is the reciprocal of the focal distance, in other words, it is such number that multiplied by the focal length gives *one* as product and it can, therefore, be expressed as $\frac{1}{f}$.

A lens having a focal length of *one meter* has been selected to express the unit of measurement. It is said to have a power equal to *one diopter* and is designated by the number 1.

Thus a lens having a focal length of 0.50 meters has a power equal to $\frac{1}{0.50}$ meters or *two diopters* and is designated by the number 2, while a lens having a focal length equal to 0.10 meters has a power equal to $\frac{1}{0.10}$ meters and is designated

by the number 10.

The measurements are the same for convergent and divergent lenses, but they are distinguished by the signs plus (+) for the positive and by the sign minus (—) for the negative lenses.

Thus, for example, a convergent lens of a focal length of 0.50 meters may be designated as a + 2 lens, while a — 2 lens would indicate a negative lens of the same focal length.

Since the index of refraction and the curvature of the two faces of the lens are the controlling factors of the power of the lens, if these entities are known, the focal length of the lens is easy to calculate.

The total curvature of the lens is obtained by adding together the reciprocals of the radii of curvature of its two faces. Thus if we call r_0 the radius of curvature of the first face and r_2 the radius of curvatûre of the second face of the lens its total curvature will be equal to $\frac{1}{r_0} + \frac{1}{r_2}$. The total curvature multiplied by the absolute index of refraction of the lens, that is to say by the refracting index less 1 (the retractivity of air), will give the power $\frac{1}{f}$ of the lens. To express this into one formula we have

$$\frac{1}{f} = (n - 1) \times \left\{ \frac{1}{r_0} + \frac{1}{r_2} \right\}$$

For example a lens whose radii of curvative are 0.50 meters for the first face and 0.10 meters for the second face and whose index of refraction is 1.5 will have a power of

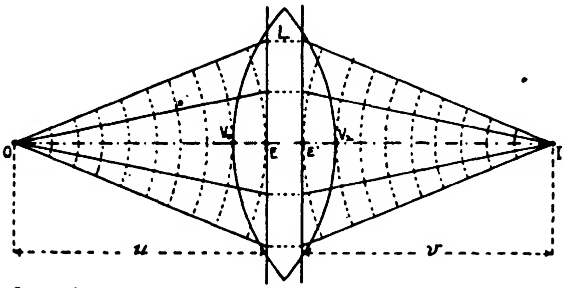
$$\frac{1}{f} = (1.5 - 1) \times \left\{ \frac{1}{0.50} + \frac{1}{0.10} \right\} = 0.5 \times (20 + 10) =$$

$0.5 \times 30 = 15$ Diopters.

Since 15 is the reciprocal of the focal length this constant

will therefore be $\frac{1}{15}$ of a meter or 2.63 inches.

When the index of refraction and the curvature of the faces of the lens are known it is also extremely easy to find its power of convergence or divergence for rays incident upon



Power of convergence of a positive lens for an object point lying at a finite distance from the lens

its first face from a luminous point situated at a *finite* known distance from the lens.

Suppose L to be a convergent lens and O a luminous object point situated on the axis at a finite distance from the lens.

This distance is reckoned from the object point to a certain point within the lens called the first principal point the characteristics of which will be described in the following paragraph.

Let us designate this distance by the letter u and the distance from the lens or better, from the second principal point of the lens to the image point I by the letter v.

The incident wave front will have a curvature $\frac{1}{u}$ to which the total curvature $\frac{1}{f}$ of the lens shall be added to obtain the resultant curvature of the wave front emergent from the lens.

By keeping present that the point from which the reckon-

ing commences is the vertex V_o of the first face of the lens and therefore the value u which *lies at the left* of V_o is a negative value, we obtain the well known formula $\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$.

If we suppose for example the distance u to be 0.50 meters and the lens to have a power of 15 Diopters, we will obtain:

$\frac{1}{u} = 2$ Diopters; $\frac{1}{f} = 15$ Diopters, and $\frac{1}{v} = -2 + 15 =$ 13 Diopters.

The distance from the lens to the image points I will then be equal to $\frac{1}{13}$ of a meter $= 0.076$ meters $= 3.03$ inches.

As one meter is equal to 39.37 inches, in order to find the number of Diopters given by a focal length expressed in inches, it is necessary to divide 39.37 by that focal length thus:

$$\text{Diopter} = \frac{39.37}{f \text{ in inches}} = \frac{1}{f \text{ in meters}}$$

and conversely; to find the focal length of a lens whose dioptric power is known, it is necessary to divide 39.37 by that number if the focal length is wanted in inches and to divide 1 by that number if the focal length is wanted in meters. Thus:

$$f \text{ in inches} = \frac{39.37}{\text{Diopter}}; \quad f \text{ in meters} = \frac{1}{\text{Diopter}}$$

Principal Points of a Lens

The principal focal points of a lens are constant for the same lens and are two of a set of *cardinal points* which are so called for their immutable constancy.

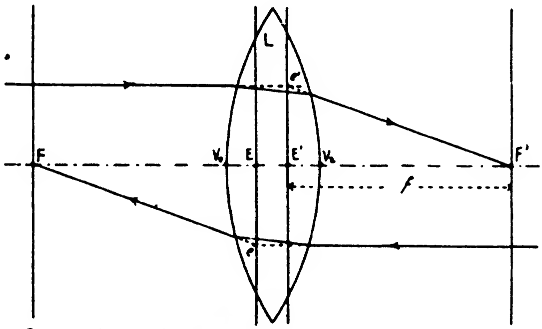
To make this clear, the principal focal points are always

to be found at the same point and on the axis of the lens, while the position of the conjugate points being entirely dependent upon the distance of the luminous point from the lens and its position in respect to the axis is variable.

The distance from the principal focal points to the lens is then also constant for the same lens but due to the *thickness* of the instrument there must be determined a certain point from which the reckoning of such distance must commence.

Two biconvex lenses, for example, may be characterized by an equal focal length, or distance, and at the same time the curvatures of their faces may be such that if the computation of the focal distance should be made from the vertices of the lens, the principal focal point, a discrepancy would be apparent resulting in serious errors in the computation of the image-forming properties of the lens.

To C. F. Gauss is due a theory on the cardinal properties



Principal and focal points and planes in a convergent lens

of image-forming optical instruments which renders extremely easy the geometrical tracing of the light rays not only through one single lens but also through systems of lenses.

Only the most elementary principles underlying the Gauss theory which apply to the formation of real images will be presented in this chapter.

The power that a lens possesses to converge the refracted rays of light is dependent upon the *n* (index of refraction)

value of the material of which the lens is made and upon the curvature of its faces.

The ray incident upon the first face of the lens, traveling from left to right and parallel to the axis will be so refracted that it meets the axis of the lens at the *focus* F′ which is situated very near the center of curvature of the first refracting surface of the lens. A ray traveling from right to left will be so refracted that it will meet the axis at F first principal focal point of the lens.

By prolonging within the lens both the incident and the refracted rays, it will be found that they meet at a certain point, *e′* for the rays traveling from left to right, and at the point *e* for the rays traveling from right to left.

The lines traced from these points perpendicular to the axis will cross it at the points E and E′ which are called the *"Principal points"* or the *"Equivalent points"* or the *"Optical centers"* of the lens.

The *true focal distance* of a lens is to be measured *from the principal focal point to the principal point nearest to it* and is designated by the small italic letter *f*.

The lines crossing the axis at the points F; E; E′ and F′ represent sections of planes also perpendicular to the axis which are called the *focal planes* or the *principal planes* according to the denomination of the points to which they correspond.

Since the position of the principal points is dependent upon the *n* value of the material of which the lens is made and of the curvature of the faces of the lens their positions vary for lenses of different material and of different curvatures.

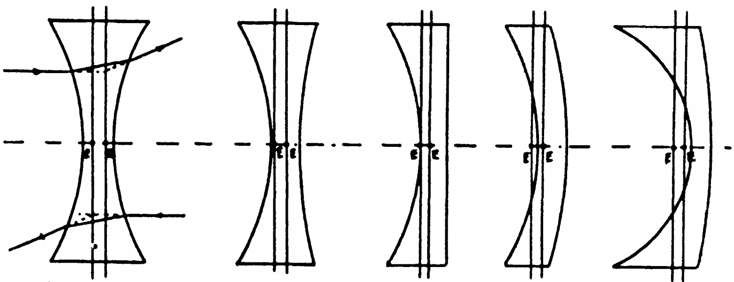
In the illustration above the *n* value of the material is supposed to be 1.5 and the curvatures of the two faces are equal to each other. In such lens the separation between the principal points is approximately one-third of the thickness of the lens and they are so located that they divide the distance between the vertices of the lens in three very nearly equal parts. For lenses of different *n* value and whose faces have different curvatures the position of the principal points

so vary that they may even be found to lie outside of the lens itself.

It will be noticed from the figure that the principal points are always displaced towards the face of the lens which has the shortest radius of curvature, that is to say towards the face whose bulge is the most pronounced.

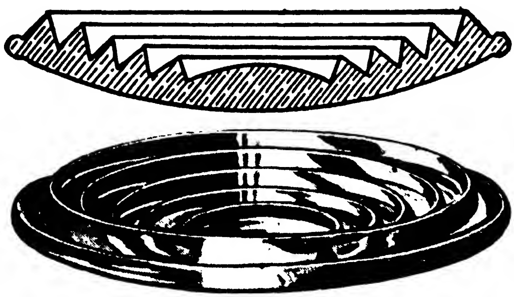
The principal points in divergent lenses may be located in the same manner as those of the convergent ones, as it is shown in the following figure representing the biconcave lens.

Again the displacement of the principal points is always in a direction towards the face of the lens which has the shortest radius of curvature.



Principal points and planes in divergent lenses

The position of the cardinal points of a lens can be calculated when the index of refraction, the radii of curvature and the thickness of the lens are known.



RESISTANCE IN ARC CIRCUITS

Two carbons set up in a standard lamp house connected cross a line supplying current at a constant voltage without a ballast would not furnish a satisfactory source of light. An electric arc has what is known as negative coefficient of resistance so that the volt-ampere characteristic does not follow Ohm's law. In other words, the voltage of an arc in a circuit without ballast decreases as the current is increased, until the voltage of the arc is not sufficient to sustain the current between the carbons. Then, the arc "snaps" out.

To overcome this, ballast in the form of resistance is connected in the circuit to limit the current and thereby stabilize the arc by maintaining a constant arc voltage. An arc stabilized in this manner provides a steady source of light. The resistance also serves a useful purpose in limiting the amount of current that flows when the arc is struck by shorting the carbons. Without this resistance in the circuit, the current drain from the supply circuit would be excessive. In certain applications, resistance is added, to that necessarily required to stabilize the arc, in order to provide a means of dropping the supply voltage to a value suitable for the arc.

The arc voltage depends on the arc gap, the size and quality of the carbons, the position of the carbons, and the current flowing in the circuit. Due to practical considerations, it is impossible to fix definite values of arc voltage within small limits.

The arc circuits are supplied energy from either the direct current service mains of a company distributing electrical power or, in an AC district, from a convertor, such as a motor generator set or rectifier, which receives alternating current from the service mains and furnishes direct-current for use in the arc circuits.

In all cases, the voltage supplied may be considered as a constant, the value depending on local conditions. The values commonly met in practice are as follows: 80, 85, 90, 100, and 115 volts. In all cases, the rheostat must be designed for the actual conditions of line voltage, arc voltage, and current range under which it must operate.

The voltage drop in the ballast rheostat equals the difference between the supply voltage and the desired arc voltage. In order to steady the arc, the value of this drop should approximate fifty per cent of the arc voltage.

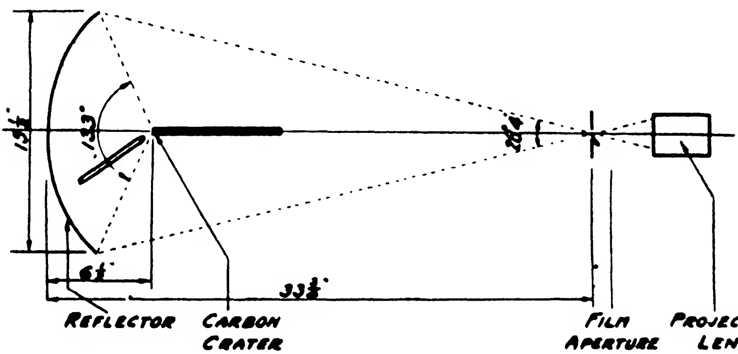


Diagram of the $f/2.0$ reflector arc system.

The manufacturers of motor generators are now advocating a minimum output of 80 volts for low intensity arcs to obtain the proper ballast action from the resistance connected between the generator and the arc. It is their contention that anything less than 80 volts results in an unstable arc which is unsatisfactory for proper projection.

For the Hi-Low and Hi-Intensity arc the line voltage must be considerably higher as in these lamps the current is higher. Therefore, the arc voltage goes up and in order to get a steady arc, the line voltage must go up in proportion.

The resistance for use as ballast may be furnished as a fixed resistor or as a rheostat consisting of a number

of resistors with means for adjusting the amount of resistance in the circuit. Resistors have been generally used for low current applications and rheostats for both low and high current arc circuits.

The fixed resistors are supplied with a resistance element of nickel-chromium ribbon formed into a U-channel and mounted on a transite bar. This construction makes a light, compact resistance unit and the ribbon presents the maximum surface possible for heat radiation.

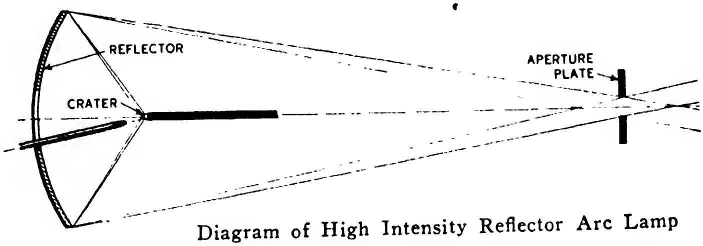


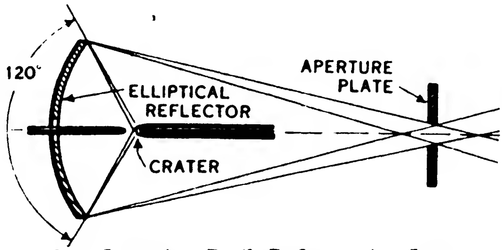
Diagram of High Intensity Reflector Arc Lamp

The variable rheostats are made up using a suitable combination of resistors to furnish the specified capacity. In order to prove control in 5 ampere steps, wire bar resistors are used for three steps of 5, 10 and 15 amperes. Wire bar resistors are made by winding an alloy resistance wire, having zero temperature coefficient, in the form of a long coil. The coiled wire is wrapped on a narrow transite support, eliminating the sagging of the wire and touching of adjacent coils.

In arc circuits having a maximum current exceeding 110 amperes, it is advisable to reduce the starting current to some value lower than that used for normal opeartion in order to avoid fracturing the carbon due to inrush current, when the arc is struck and to obtain a satisfactory crater in the positive carbon. To provide the reduced current, usually from 1/2 to 2/3 of normal current, an extra terminal is placed on the rheostat. The fixed section of the rheostat is generally connected to this terminal thereby providing a circuit in which the current is limited to the minimum current as specified

on the rheostat name plate.

Two wires from the rheostat are carried to the lamphouse and connected to knife switches. The lead from the fixed section of the resistance is connected to one side of the double pole switch and the lead from the variable section to the booster switch. Then the current in the circuit when striking the arc after closing the double pole switch is a minimum. After the carbons are warmed and the crater formed, the normal current is supplied by closing the booster switch.



Low Intensity, D. C. Reflector Arc Lamp with Elliptical Mirror

The use of the booster circuit increases the importance of the minimum current specified for the rheostat. For example, a rheostat having a rating of 60-180 amperes normally operating on 150 amperes would have a warming-up current of 60 amperes. This current is too low to be practical with carbons rated at 150 amperes, but by fixing the minimum current at 90 amperes, the desired heating and burning would be obtained. However, the boosting current need not limit the specifications of the minimum current because it is always possible to obtain any desired current below this value.

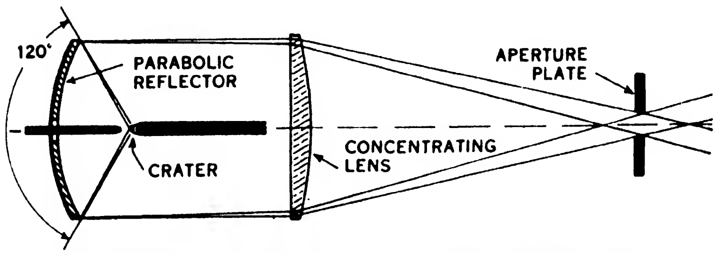
A rheostat rated at 150-210 amperes may be connected so as to furnish a warming-up current of 60 or 90 amperes by supplying an extra terminal. With the increased use of higher amperages in arc circuits the use of booster circuits will become more general.

INSTALLATION

The use of increased current on arc circuits in order

to provide suitable light on porous screens results in higher wattages in the ballast rheostats than was the practice before the use of sound in the theater. The present trend in theater design is to provide separate rooms for the rheostat equipment fitted with suitable racks for mounting the rheostats above the floor level and equipped with fans and ventilators for providing continuous air circulation.

Under any circumstances, it is important that sufficient ventilation be provided to carry off the heat



Low Intensity, D. C. Reflector Arc Lamp with Parabolic Mirror

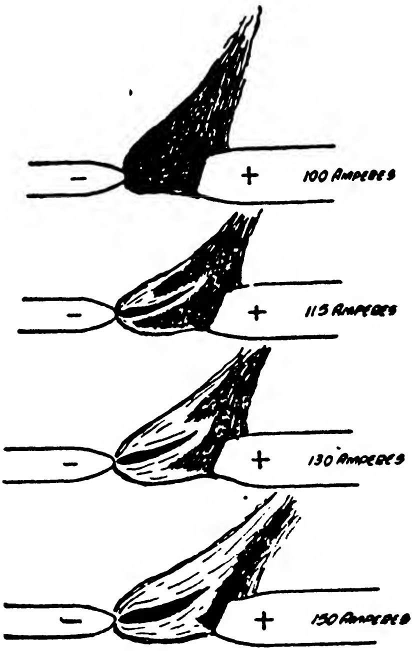
given off by the rheostats be so placed as to insure free circulation of air through the resistance elements. The fact that a rheostat becomes heated, when carrying current, is to be expected as its function is to dissipate energy in the form of heat, but it must not be placed in such a position or covered over so that the heat cannot be freely radiated.

In any carbon arc, no matter of what kind, the main considerations are amount of current, voltage across the arc, and length of arc. These are all interdependent, yet if two of the three are fixed, it does not mean that the third will always assume a definite value. This is true largely because, while we have done nothing to change the apparent length, the flow of the arc may have assumed a new path with a different resistance.

This apparent discrepancy seems to bedevil the Suprex arc more than some of the older types. Horizontal operation, together with the very special construction and materials of the carbons, probably explain this.

Lengthening the arc increases the voltage across the arc or decreases the amperes, or does a little of each—usually, but not necessarily.

Quite often when operating an arc on a ballast of fixed resistance and with a supplied voltage so steady that there was no discernable variation, the current is found to vary, sometimes abruptly and sometimes peri-



-The transition stage from the commingled two-direction discharge to the single-direction discharge, demonstrating the backing out of positive ions.

odically, especially if the current strength is not suited to the size of carbon used. It is this condition that is mystifying and leads to a suspicion as to the infallibility of Ohm's Law.

The Suprex arc today is operated either off a generating source of constant voltage with a ballast resist-

ance, or off a source having what is known as a drooping characteristic, that is, as the demand for current increases the voltage produced by the generating device decreases. With the drooping characteristic it is possible to operate without the use of ballast, but two arcs cannot be burned simultaneously from the same generating source.

With the other plan, using a constant voltage source, this voltage is held somewhat higher than that required for the arc, the difference being consumed in the ballast. In this manner two or more appliances can be used at one time, and the arc in each will burn independent of all the others. The Suprex arc is particularly adapted to this sort of operation because the ballast resistance required is small, being on the order of 6 to 10 volts in place of the 25 to 30 usually employed with the higher voltage arcs.

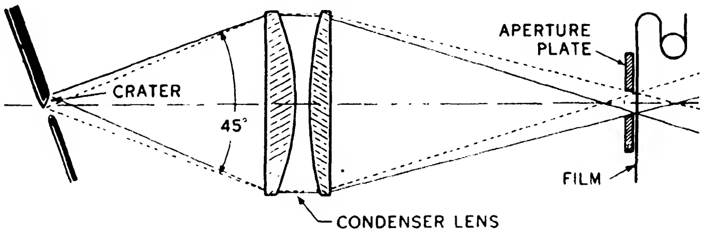


Diagram of Old Type, Low Intensity, D. C. Projection Lamp

Supposing, then, an arc is burning on a constant voltage source with a ballast in series. The voltmeter, if steady, will show that the generator output is constant. If the voltage should change, the voltmeter would tell how much, just when, and for how long.

The ballast, adjusted with a certain position of the handle or with a certain combination of short-circuiting clips, has a very definite resistance, which means that with a given current in amperes the voltage across the ballast can be only one definite thing. The one thing that cannot be controlled is the *resistance of the arc itself.*

All of which leads us to an important conclusion.

If the voltage remains constant as shown by the meter across the generating source while the current is fluctuating, the current source cannot be blamed for these fluctuations.

Suspicion will fall next on the ballast. Herein is always present a possibility of poor or loose connections, which are really the only cause of rheostat trouble. To detect such trouble is not so easy, since the voltmeter across the rheostat or ballast will keep step with the fluctuations of amperes in the arc because our old friend Ohm's Law is in full force and *if the resistance remains constant, as it should, and the current changes,*

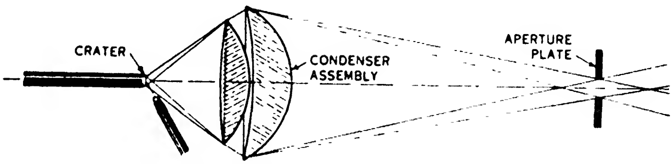


Diagram of High Intensity Arc Lamp—Condenser Type

the voltage drop across the ballast will change up or down in proportion to the current change.

One way of detecting rheostat trouble is to look for hot spots. The writer has found rheostat installations in which the series ribbon type is used, and where the resistance value is adjusted by the cutting out or in of clips on the front, where the clips had not been tightened and were so hot as to burn the hand.

Another way of checking ballast is to put a voltmeter across its terminals and watch it in conjunction with an ammeter. If at any time a fluctuation of the voltmeter can be detected when the ammeter is steady, the trouble is definitely located in the ballast.

Ballast resistances, of both the series and the multiple type, are so constructed today that very fine gradations of current values are possible and usually no adjustment of the field regulator is required.

CARBONS AND THE CARBON ARC

The carbon arcs used in the motion picture industry are of three general types — the low-intensity arc, the flame arc, and the high-intensity arc. The low and high intensity arcs have been used in both motion picture photography and in projection, although the former is now obsolete in photography and is steadily being replaced by the more efficient high-intensity type in the projection field as well. The most important use of the flame arc in the motion picture industry is in photography, where it provides a broad beam of suitable color quality for general set illumination. The system of nomenclature that has grown up with the industry is more descriptive of certain types of lamp than of the character of the arc. Names such as "mirror arc," "Hi-Lo," "Simplified High-Intensity," "M. P. Studio," "Baby Spot," and "Sun-Arc" are in common usage, but some of these terms are not descriptive of either the arc itself, the mechanism, the optics, or the service. It is the purpose here to define the arc itself, irrespective of the other factors just mentioned, so that a given trim may be readily classified as to whether it is a low-intensity, a flame, or a high-intensity arc.

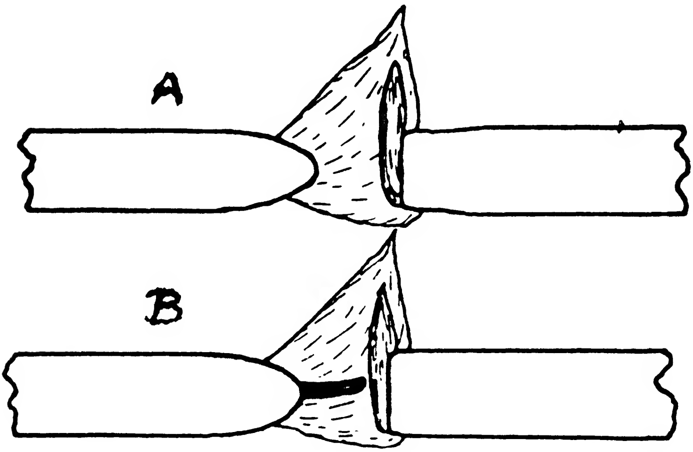
As a basis for classification, the physical nature of the light-source offers the most logical distinction. Therefore the definitions have been phrased from this standpoint, followed in each case by descriptive material in their support.

THE LOW-INTENSITY CARBON ARC

The low-intensity carbon arc is one in which the principal light-source is incandescent solid carbon at or near its sublimation temperature.

In the vast majority of cases, this arc is operated on direct current, although a few carbons are still sold

for alternating-current service. The direct-current arc uses neutral cored positive electrodes and either solid or cored negative electrodes. A neutral cored carbon contains a core consisting predominantly of carbon, less dense than the surrounding shell, and incorporating a small percentage of an arc-supporting material such as a potassium salt, which does not contribute significantly to the light. "White Flame A. C." carbons are used in the alternating-current, low-intensity arc. The

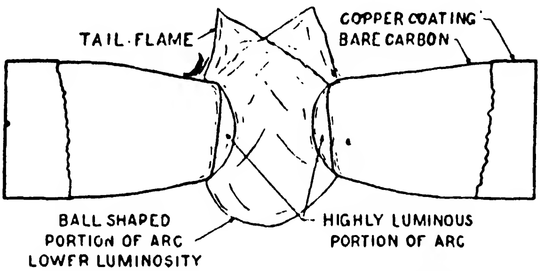


Sketches showing the appearance of the direct-current arc with coaxially aligned electrodes: (*A*) With no negative "tongue"; (*B*) with negative "tongue."

core of these carbons contains flame-supporting material the function of which is to steady the arc, quiet the hum, and whiten the light. In the direct-current arc, the crater face of the positive electrode is used as the light-source for projection, since it operates at a much higher temperature than the negative electrode and so provides about 90 per cent of the total light from the arc. The bright spot on the end of this positive carbon has a rather sharply delineated boundary which is called the anode spot or the positive crater. This crater marks the region within which most of the elec-

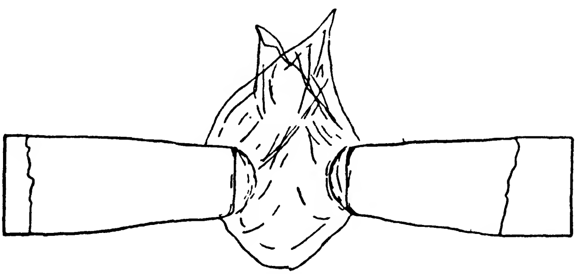
tric current passes between the anode and the arc stream.

The surface of the crater is heated to its high temperature as the result of the absorption of energy from electrons discharged there, and the absorption of ener-



80 amperes, 25½ volts; good operating conditions.

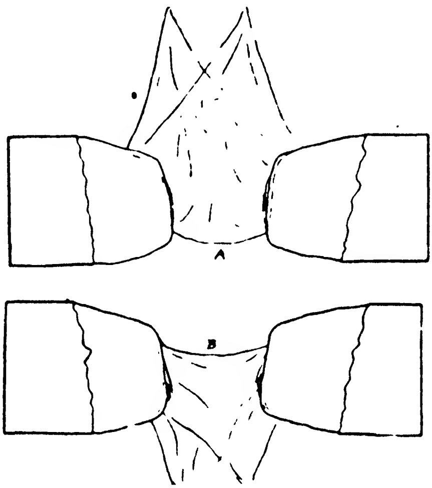
gy from the gaseous region known as the anode layer directly in front of the anode. The arc gas in the major part of the arc stream is very hot, having a temperature of 6000°C or more, and is therefore highly ionized. In its highly ionized condition, it can carry the current with a fairlv low voltage drop per unit length.



8-mm. a-c. high-intensity carbons, overloaded: 90 amperes, 35 volts.

amounting to about 20 volts per centimeter. In the anode layer, however, the gas is cooled by the proximity of the anode to such an extent that its degree of ionization, and therefore its electrical conductivity, is

very low. Because of its low electrical conductivity and because of space-charge effects, a high voltage drop must be concentrated in the region of this anode layer in order to force electrons through it and thus conduct the arc current. This voltage is called the anode drop, and is of the order of magnitude of 35 volts for a low-intensity arc.

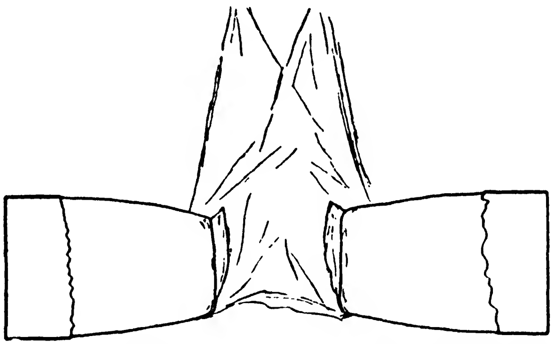


8-mm. a-c. high-intensity carbons, underloaded· 60 amperes 24 volts; showing different positions of the arc as it "flops" about

This energy dissipated at the anode heats it to incandescence, the maximum temperature obtained being limited by the sublimation temperature of carbon. This limits the maximum brilliancy of the low-intensity arc to a value of about 175 candles per square-millimeter. The area of the anode spot or crater adjusts itself for a given current so that the heat input is sufficient to bring the crater to a value near this sublimation temperature. An increase in current in the low-intensity arc will, therefore, not increase appreciably the maximum brightness, but will increase the area of the crater surface. Compared to a high-in-

tensity arc, the current-density of a low-intensity arc is quite low. For the familiar commercial lamps, the current-density in the positive carbon ranges from approximately 50 to 200 amperes per square-inch.

It is interesting to observe that carbon is an ideal material for use as an electrode in such an arc, because it remains a solid at a higher temperature than any other substance of suitable electrical and thermal conductivity, so that a more brilliant light may be produced; while its property of volatilizing directly from a solid to a gaseous state permits convenient disposal of the consumed portion without danger to the associated mechanism.



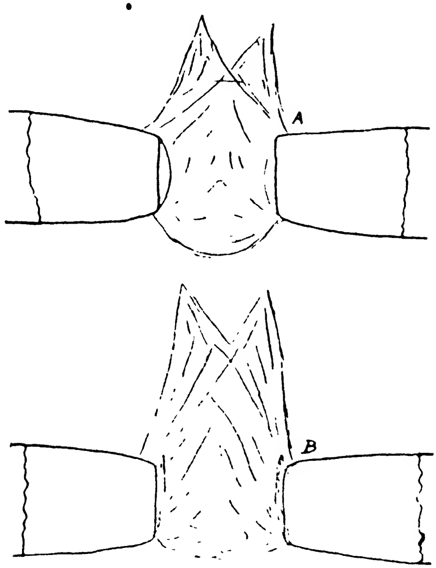
8-mm. a-c. high-intensity carbons: 80 amperes, 26 volts; medium arc length, arc disturbed by external forces.

THE FLAME ARC

A flame arc is one in which the entire arc stream, made luminescent by the addition of flame materials, is used as a light-source.

The flame arc was a natural development from the low-intensity arc, obtained by enlarging the core in the electrodes and replacing part of the carbon there by chemical compounds capable of radiating efficiency in a highly heated gaseous form. Those compounds are vaporized along with the carbon and diffuse throughout the arc flame, rendering it luminescent. The high concentration of flame materials in the core

reduces the area and brilliance of the anode spot so that, at the low current-densities used in flame arcs, the contribution of the electrode incandescence to the total light becomes unimportant. The evaporation of flame materials is low relative to that obtained in a high-intensity arc, and the resulting concentration of flame elements in the arc stream is low so that a high brilliance does not result. Since the whole flame is made luminous, however, the light-source is one of large area and the radiating efficiency is high.



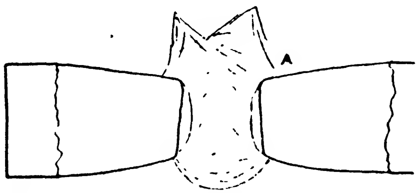
8-mm. a-c high-intensity carbons: 80 amperes, 28 to 29 volts; (*A*) long arc length, good operating conditions; (*B*) long arc length, poor operating conditions.

The radiation emitted by the flame arc consists chiefly of the characteristic line spectra of the elements in the flame material, and in the band spectra of the compounds formed. The rare earth metals of the cerium group are used as flame materials where, as in most cases, a white light is desired, while calcium salts are used to give a yellow light and strontium salts red.

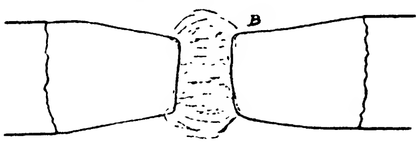
THE HIGH-INTENSITY CARBON ARC

The high-intensity carbon arc as used for projection is one in which, in addition to the light from the incandescent crater surface, there is a significant amount of light originating in the gaseous region immediately in front of the carbons as the result of the combination of a high current-density and an atomsphere rich in flame materials.

To produce a direct-current high-intensity arc, the positive carbon must be cored with chemical compounds similar to those used in flame arc electrodes. The current-density, however, is much lighter, so that the anode spot spreads over the entire tip of the carbon, resulting in the rapid evaporation of flame material as well as carbon from the core. Since flame material is more easily ionized than carbon, its presence in the anode layer results in a lower anode drop at the core area



(*A*) short arc length, good operating conditions;



(*B*) short arc length, poor operating conditions.

than at the shell of the carbon. This tends to concentrate the current at the core surface, resulting in the hollowing out of a crater as the current is increased. The rapid evaporation of the flame material produces a high concentration of this efficiently radiating gas in the crater and immediately in front of it. This gas, of

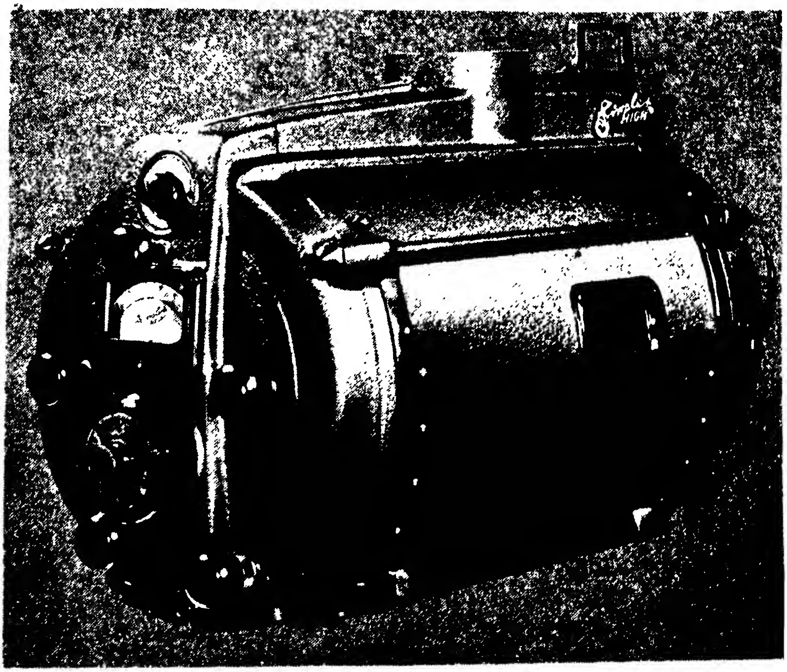
course, radiates in all directions, even back toward the crater surface, and consequently tends to serve as a blanket preventing the radiative cooling of the crater face. The heat liberated at the crater face must then be dissipated entirely through evaporation of more flame material and through conduction back along the positive carbon. This, of course, tends to increase the evaporation of material within the crater and aids in the tendency for crater formation. Thus in a high-intensity arc there is a close correlation between the crater depth and the brilliancy of the arc gas within and immediately in front of the crater; for a given type of positive carbon, there is a linear relationship between the crater depth and the excess brightness over that of a low-intensity arc.

An increase of current in a high-intensity arc increases the crater area only slightly, but produces a marked increase in brilliancy. The maximum brilliancy of the crater obtained in various types of direct-current high-intensity arcs used in common commercial lamps ranges from 350 to 1200 candles per square-millimeter with current-densities in the positive carbon ranging from 400 to well over 1000 amperes per square-inch. Experimental carbons have been produced with brilliancies in excess of 1500 candles per square-millimeter.

The increased brilliancy of a high-intensity over that of a low-intensity arc is produced by radiation from the high concentration of flame materials within the confines of the crater. The thermal energy supplied by the electrical power input to the arc continually excites the atoms of the flame materials to higher energy states, and the excess energy of these atoms is being continually released in the form of radiation. The high density of radiation results in the production of a strong continuous spectrum in addition to the line spectrum of the flame elements. Since radiation in the visual range of wavelength from 4000 to 7000 Angstroms is required in motion picture services, the most efficient compounds to use as flame materials are those producing the most radiation in this spectral band. Nothing better than the rare earth metals, of which

cerium, lanthanum, neodymium, and praesodymium are typical examples, has ever been found for this purpose. With complex atoms having many electrons, countless opportunities for the energy exchanges that give rise to radiation in the visual region are provided, so that no one part of the spectrum is unduly exaggerated, and a while light is naturally produced.

The alternating-current high-intensity arc is also a true high-intensity arc within the meaning of the definition proposed. The high current-density and the high concentration of flame materials combine to produce light both from the incandescent electrode and from the gaseous region immediately adjacent, as they do on direct current.



COMMERCIAL ARC LAMPS

PEERLESS HY-CANDESCENT ARC

After temporarily fastening the lamphouse to the pedestal, note the vertical threaded stud No. 15259, Plate P-40, at the front inside of the lamphouse base. Also note the slot in the center of the separator bar at the rear of the lamphouse base plate. It is at these two points that the burner assembly is adjusted, to align it with the optical axis and also fastened to hold it securely in position in the lamphouse.

As the burner is independently adjustable, both laterally and vertically within the lamphouse, there is provided a marker at the front and rear end of the lamphouse base which, when aligned with the markers on the burner base, will indicate the burner is in the center of the optical axis of the lamphouse.

It does not necessarily follow however, that with the alignment of these markers, the axis of the burner is in optical alignment with the projector mechanism, and it may be necessary to adjust the burner to a slightly different position to attain that result.

INSTALLING BURNER

The manual carbon adjustment shafts No. 15042 and No. 15043, Plate P-41, and the negative carbon clamp arm with No. 15128, Plate P-42, asbestos lead wire, are removed for shipment.

Before installing the burner in the lamphouse, pin the above carbon adjustment rods with the taper pins provided, see Plate P-41. The longest shaft No. 15043 should be used in the lower hole and short shaft No. 15042, Plate P-41, in the upper hole.

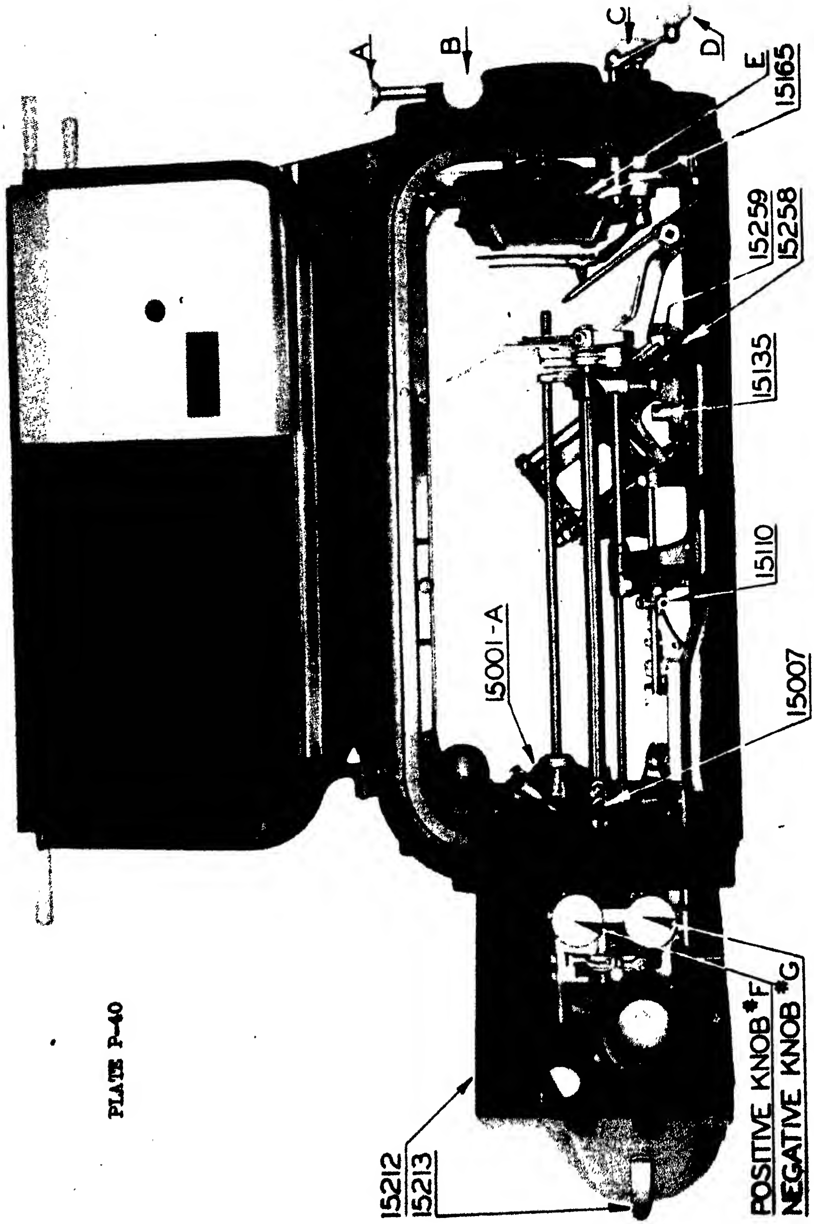

A
B
C
D
E
15165
15259
15258
15135
15110
15007
15001-A
15212
15213
POSITIVE KNOB #F
NEGATIVE KNOB #G

PLATE P-40

Attach the No. 15085, Plate P-41, negative carbon arm to the feed unit, with the four screws provided, first passing the screws through the holes in the No. 15371 carbon holder heat shield before tightening in place over the dowel pins. Note that the negative carbon arm may be removed for cleaning or replacement without disturbing its insulation.

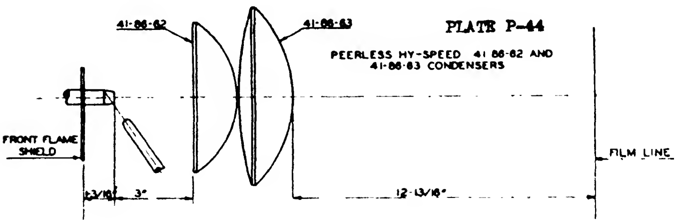
Next pass the terminal on the free end of the No. 15128, Plate P-42, asbestos lead wire into the front hole in negative terminal clamp bracket No. 15129 and securely tighten the scren. Never tighten terminal clamp screw No. 4149 in the negative carbon holder when the No. 15126 pigtail terminal is not inserted therein as doing so may crack the cast iron clamp.

Now remove the upper No. 15258, Plate P-40, nut and washer on the No. 15259 vertical threaded stud found near the front of the lamphouse base. Do not remove the lower nut or washer. Remove panel from the rear of the lamphouse and lift the complete burner without large flame shield into the lamphouse through the rear opening, and place the slot seen at the front end of the burner base over vertical stud No. 15259, Plate P-40, until it rests on the lower washer and nut, and align the groove on the top of the stud with the groove that will be seen just to the side of the slot in the burner base. Next, put the upper washer in place, curved side up, and the upper nut curved side down, and screw the nuts up or down until the top of the stud is parallel with the top of the burner base at the point where the groove is located thereon and tighten the upper nut only slightly.

Insert the cap screw through the slot at the rear end of the lamphouse base and screw it into the threaded hole on the under side of the burner base and tighten only slightly. The vertical groove or marker on the rear end of the lamphouse base indicates the center of the lamphouse and another groove will be seen on the under side of the burner base casting. When these grooves are in alignment, the rear end of the burner is also in the center of the lamphouse.

Connect the No. 15483-A, Plate P-42, meter shunt lead wires to the ammeter. The lead wire having the "RED" indicating mark should be connected to the meter terminal identified by the "PLUS" mark just below the terminal.

Connect the main asbestos lamp leads from the projector switch to each of the No. 15126, Plate P-42, slip terminals provided for their ends and insert each in their clamp brackets No. 15129 and securely tighten clamp bracket and the positive to the rear clamp bracket as indicated on the decalcomania on the lamphouse base directly under the terminal brackets.



TO ALIGN BURNER

Remove the projector lens and place the dummy lens barrel in the projector lens mount and tighten in place. Insert the pointed end of the alignment rod from the front through the holes in the center of the dummy lens barrel, and through the projector aperture, being sure the fire and rotating shutters are in an open position.

Next remove the flame shields at the front of the burner from their support cradle and insert the special trimming wrench in the upper hole in the No. 15110, Plate P-40, contact release cam and depress it until it stays open, which releases the pressure on the positive carbon contacts, and lay the contacts on the lamphouse base without disconnecting the shunt ribbons. This makes the positive carbon guide accessible.

Open the lamphouse dowser and pass the alignment rod up to the positive carbon guide and note the

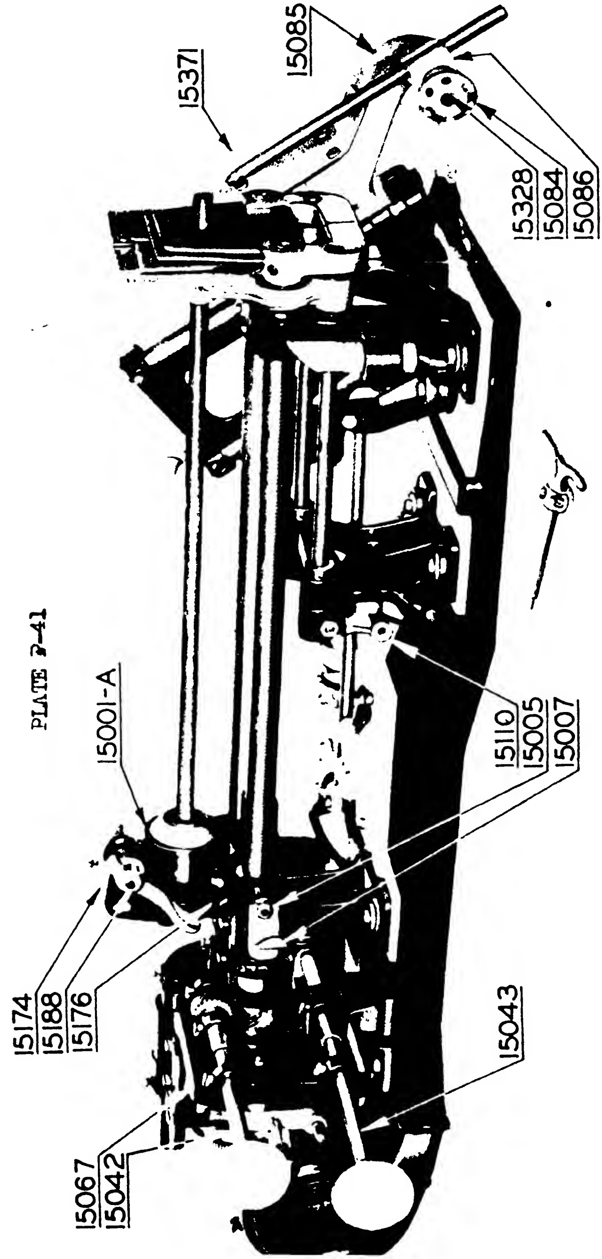
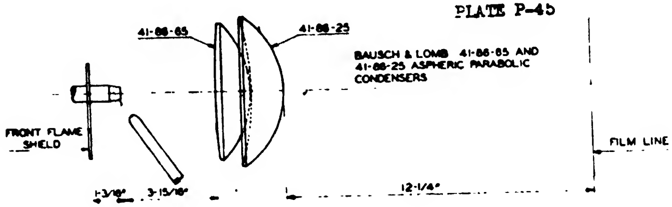

15371
15085
15328
15084
15086
15001-A
15110
15005
15007
15174
15188
15176
15043
15067
15042

PLATE 2-41

position of the hole in the guide in respect to the pointed rod. If the projector pedestal top is provided with lateral and vertical adjustments, raise, lower or move laterally the entire lamphouse, by means of the pedestal to adjustments, until the pointed rod can freely enter the hole in the carbon guide without touching the sides of the hole. Care should be used to try to keep the rear of the burner in fair alignment with the front end thereof and the aperture. When the pointed aligning rod freely passes through the hole in the positive carbon guide, the front end of the burner is in alignment with the optical axis of the projector.

PLATE P-45



Move the No. 15001-A, Plate P-40, positive carbon rotating head back to the rear of the burner and clamp the steel rod near the rear end of the rod, and move the rotating head forward until the point of the rod is at the projector aperture plate. Center the point of the rod in the center of the aperture by means of the pedestal top adjustments at the rear of the pedestal top without disturbing the adjustments made at the front of the pedestal. Since adjusting the rear of the pedestal will also slightly affect front of the lamp, the aligning rod should again be removed from the burner and inserted in the lens dummy and its alignment with the positive carbon guide again carefully and make further adjustments to the front of the pedestal as are needed to put the positive carbon guide in exact alignment with the rod.

All pedestal adjustments should then be tightened and the nut on the vertical stud at the front of the burner and the screw at the rear of the burner tight-

ened to hold the burner in that position.

If lateral adjustment only can be made on the pedestal top, make lateral adjustment by that means for alignment of the positive carbon guide and make lateral alignment of the rear of the burner by means of the slot at the rear end of the lamphouse base and up and down adjustments of the front of the burner by means of the nuts on the vertical threaded stud No. 15259, Plate P-40.

BURNING POSITION OF CARBONS

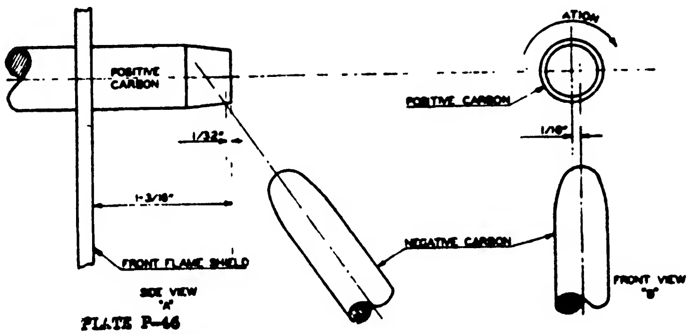


PLATE P-46

If no adjustments are provided on the pedestal top, all alignment adjustments should be made on the burner itself by means of the slot and the nuts at the front end of the burner base and the slot at the rear of the lamphouse base.

It should be noted that alignment of the rear of the burner is of secondary importance and alignment of the front end is of primary importance.

INSERTING CONDENSERS IN MOUNTS

The condenser mount is comprised of three separate pieces. A main body, a lens separator and a threaded retainer ring.

To insert the lenses in the condenser mount, first place the mount on a flat surface with the threaded ring facing up, unscrew it and remove both the ring and the lens separator.

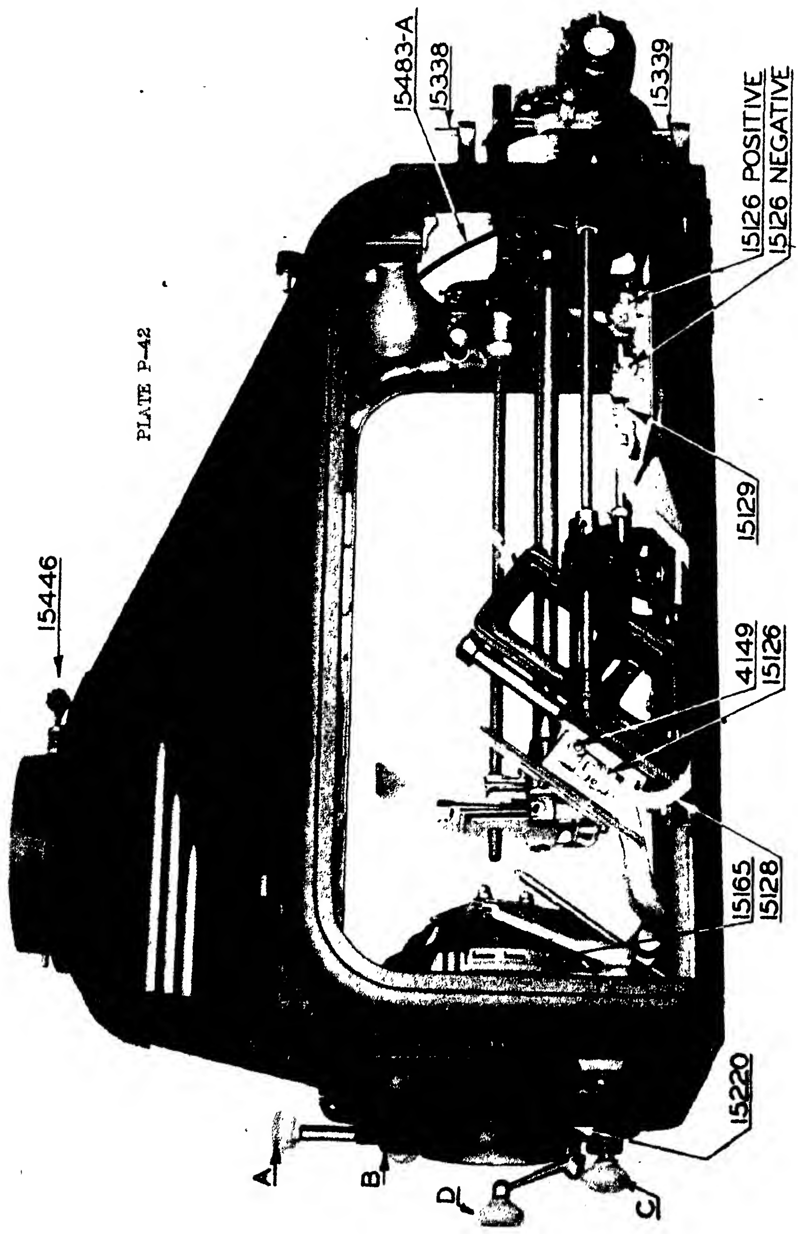
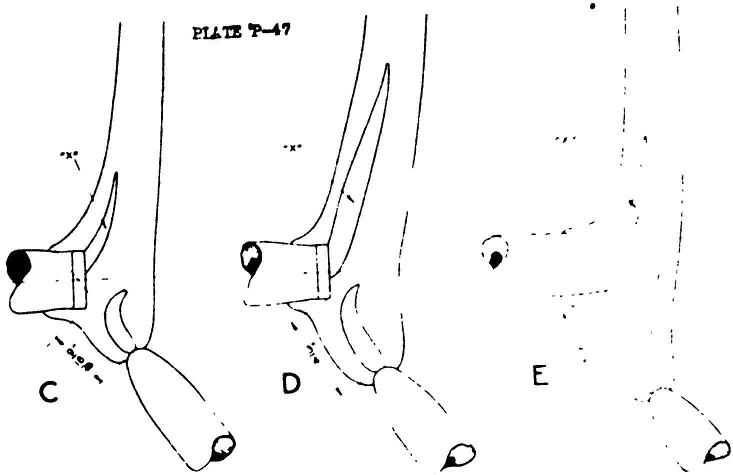

15483-A
15338
15339
15126 POSITIVE
15126 NEGATIVE
15129
15446
4149
15126
15165
15128
15220
A
B
D
C

PLATE P-42

Place the smaller of the two condensers in its recess at the bottom of the mount with the strongest curve facing upward, next insert the spacer ring on top of the rear lens, and then place the larger lens in its recess in the retainer ring with its strongest curve also facing upward. Now screw the threaded retainer ring into position until it contacts the front lens and then unscrew it about 1/6 of a turn or as required to provide sufficient room for the expansion of the lenses when heated.

PLATE P-47



After this, tighten the retainer ring set screw to hold the lens retainer ring securely at that seting.

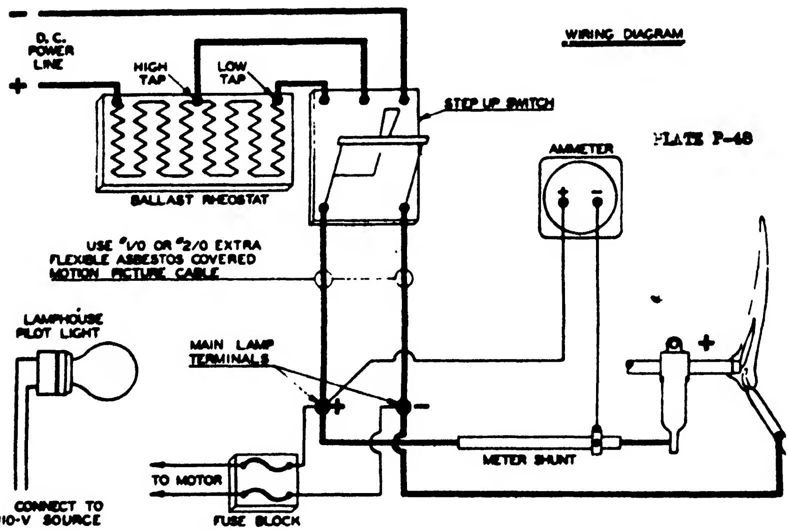
When using Bausch & Lomb No. 41-86-25 and No. 41-86-65 Parabolic-Aspheric Cinephor condensers, note that the rear surface of the rear lens is cylindrical. Its correct operating position is when the markers on the outer edge of the lens coincide with the markers on the face of the condenser mount casting. Due to its cylindrical rear face it is important that the lens retainer ring be unscrewed enough to allow the rear lens to be turned one-half of a revolution in the mount and still have expansion space at all positions of the half turn.

To correctly place the condenser mount in its supporting cradle No. 15165, Plate P-40, the position of

the handle on its outer periphery should be 30° to the right of vertical.

This is not only a convenient position for handling but it also brings the two "resting" lugs "E," also on the outer periphery of the mount, to the correct positions where they will rest on each end of the support cradle when the mount is placed in the cradle.

Working distances for the Hy-Speed F-2 condenser system and Bausch & Lomb No. 41-86-25 and No. 41-86-65 Cinephor lens system are designated, Plates P-44 and P-45.



After setting the carbons, by turning the condenser lens focusing screw, move the condenser mount in or out, so that the distance between the rear surface of the rear lens and the front face of the positive carbon is correct for the condenser system used.

Next slide the entire lamphouse forward or backward on the pedestal until the designated distance is obtained between the center of the front condensing lens and the film line in the projector mechanism.

Do not immediately tighten the lamphouse to the

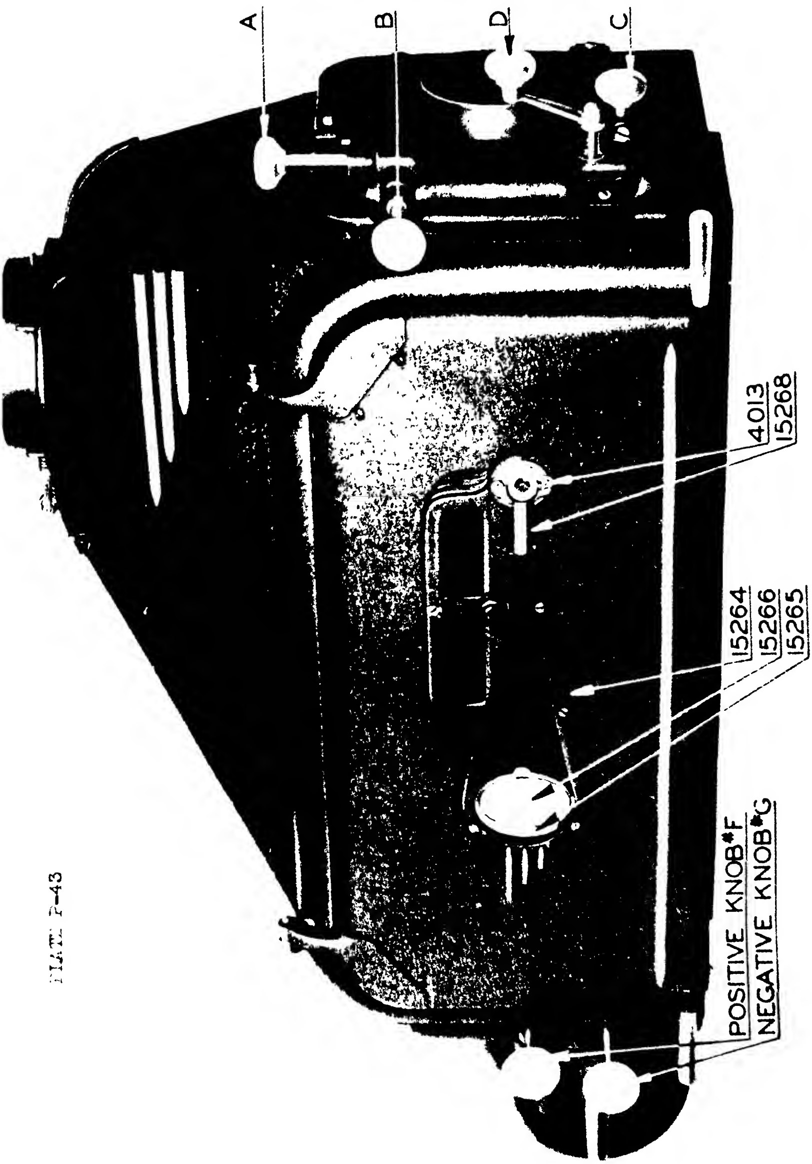

A
B
D
C
4013
15268
15264
15266
15265
POSITIVE KNOB*F
NEGATIVE KNOB*G

PLATE P-43

pedestal, as it may be found that best light coverage is obtained at a point slightly ahead or back of the indicated working distance. Hence, the proper point at which to permanently clamp the lamphouse should be determined by projecting a clear light field on the screen and moving the lamphouse a little closer or further away from the mechanism and focusing the condenser likewise, at each point of trial.

To afford greatest possible protection to the lenses, particular attention should be given to closing the light dowser "D," Plate P-42, before each lighting of the arc and also immediately after the arc has been extinguished. The Peerless Hy-Candescent lamp has a current range from 120 to 180 amperes.

Drawings "A" and "B" Plate P-46, clearly show the burning position of the positive and negative car bons that will, as a general rule, be found correct.

There are cases that may require slight deviation for best results and such deviation has only to do with the position of the positive carbon crater.

For example: In actual operation it may be found that better burning of the arc will result if the positive crater is maintained slightly ahead or slightly behind the negative intersection point as shown in the diagram.

When the advantages of so doing are evident, adopt the position found best and record it on the arc imager by making a vertical pencil line at the end of the pro jected image of the burning positive carbon on the ground side of the glass arc image screen.

To emphasize the importance of constantly maintaining the correct burning relationship of the positive and negative carbons, we illustrate in drawings "C," "D" and "E," Plate P-47, three distinctly different positions of the carbons at which it is possible to obtain identical arc amperage and voltage on the same ballast rheostat setting.

C—Shows the positive carbon too far to the rear of the negative carbon. (120-A, 66-V).

D—Shows the correct burning position. (120-A, 66-V)

E—Shows the positive carbon too far ahead of the negative carbon. (120-A, 66-V).

Note that in the correct position illustrated in "D" that the positive core flame tongue "X" appears to have been flattened out and is longer in length. This is ideal, as it is only under these conditions that the arc crater emits the maximum volume of light.

POSITIVE CARBON—MANUAL ADJUSTMENT

By means of the upper knob "F," Plate P-43, at the right rear end of the lamphouse, the positive carbon may, at any time, be manually adjusted forward or backward as required.

NEGATIVE CARBON—MANUAL ADJUSTMENT

Manual adjustment of the negative carbon is by means of the knob "G," Plate P-43, directly below the positive hand knob. By pushing inward to disengage the feed gear and worm and holding inward, then turning the knob, the negative carbon holder may be moved up or down.

Removal of the hand from this knob at the finish of an adjustment will cause the gears to automatically re-engage and motor feeding will instantly resume.

INSERTING CARBONS

First by means of the No. 15007, Plate P-40, handle on the No. 15001-A positive rotating carriage, slide the carriage to its most rearward position. Open the positive carbon collet by turning the No. 15188 lever at the top of the carriage in a forward or clockwise direction as far as possible.

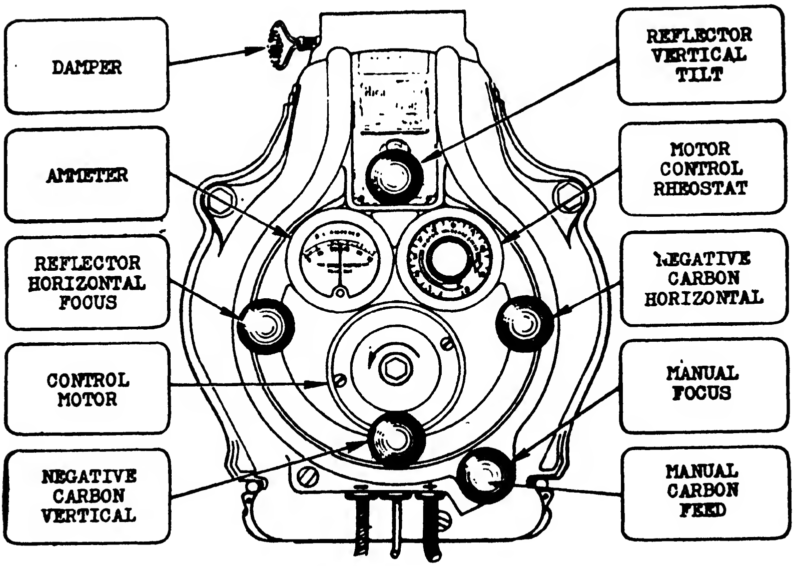
From the rear of the lamphouse pass a positive carbon through the collet to the positive contacts, insert the trimming wrench in the lower hole in the No. 15110 contact release cam and depress it until the wrench handle contacts the base of the lamphouse and pass the carbon through the contacts until its end is approximately 1-2/16" ahead of the front flame shield.

Next turn the No. 15188, Plate P-41, lever at the top of the positive rotating carriage, back to its original position to clamp the carbon in the collet and remove

the trimming wrench from the No. 15110, Plate P-40, contact release cam.

Before clamping the negative carbon in the holder see that the No. 15085, Plate P-41, carbon holder is moved to the bottom of its travel, insert a negative carbon in the No. 15086 clamp and leaving 5/8" to 3/4" distance between its upper end and the positive carbon for the arc gap, tighten the carbon securely.

After this and before striking the arc we suggest that by means of hand control knob "G," Plate P-40, the negative carbon be raised to about 1/16" from the positive carbon so that only a slight turn of the knob will be required to strike the arc.



ARC IMAGE PROJECTOR

Mounted to the outside of the right lamphouse door is the No. 15268, Plate P-43, arc imager lens holder. The image of the burning arc is picked up by a mirror and reflected through lenses mounted inside of the holder that focus it on the ground glass screen No. 15266.

The lens holder is adjustable and the image of the

arc may be moved in all directions to properly locate it on the No. 15266 screen. By loosening screws No. 4013 which hold it to the lamphouse door and moving the entire lens holder No. 15268 straight forward or backward on the No. 15264 door glass frame, the projected image can be moved to the right or left on the screen. Movement of the image up or down is had by tilting the lens holder in a like direction.

The screen holder No. 15265 with screen, Plate P-43, may be tilted if desired, so that the projected image of the arc does not have to be viewed at a distorted angle as would be the case if the projection angle was exceedingly steep.

Do not attempt to mark the burning position of the carbons by drawing a line with a straight edge on the ground side of the No. 15266 image screen until after the lamphouse and burner have been optically aligned with the projector and the final lamphouse to pedestal setting is made and the entire installation completed.

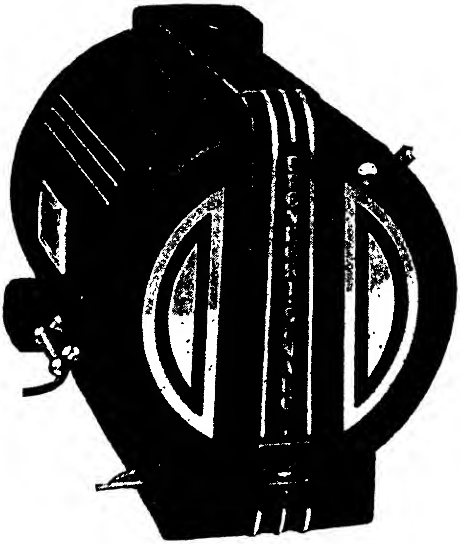
BRENKERT

RELEASE the positive carbon feed rollers and contacts by drawing release handle on the positive head to the right. Insert a 9 mm. high intensity carbon and close contacts and feed rollers by moving this handle to vertical position. By means of the positive hand feed handle move the positive carbon forward or back until its burning end coincides with arc setter pin on the positive baffle plate. By means of the negative manual feed handle adjust the negative carbon jaw to within half an inch of extreme back position. Insert in this negative holder a 5/16 x 9 cored, copper coated carbon in proper position to allow a 1/4" gap between the positive and negative carbon points. (The negative head must be locked in back position when making this adjustment). Release the negative swivel lock handle which permits the negative holder to tilt forward allowing the negative carbon to touch the positive carbon. The arc is now ready to be struck.

Make certain the generator is delivering its rated voltage

and the arc rheostats adjusted to give amperage desired. Strike the arc by closing the switch on the picture machine base. The magnetic striker will automatically swivel the negative holder to its backward position thereby striking the arc.

The positive carbon is rotated and fed forward continuously. The negative carbon is not rotated and is fed forward intermittenly. The motor feeds both carbons and therefore varying the speed of the motor varies the rate of feed of both carbons. As the ratio of consumption of the positive and negative carbons varies according to the arc amperage the negative feed mechanism is provided with a feed adjustment separate from the positive feed. The entire lamp mechanism



Overall exterior view of Senarc

should be thoroughly warmed by burning the arc for ten minutes before attempting to regulate the automatic feeds.

Regulate the speed of the motor, by the potentiometer adjusting handle on the right side of the lamp base, until the positive carbon is being fed at the proper speed to maintain its crater coinciding with the arc indicator pin on the positive

baffle plate. Next set the small reflecting mirror on the right hand lamphouse door so that the image of the positive carbon is reflected to the cardboard screen at lamphouse top. Swivel this mirror until the face of the positive carbon coincides with the vertical line marked "positive" on this card. Securely set the mirror in this position. Next adjust the automatic feed of the negative carbon by proceeding as follows: Remove the cover of the transmission unit, exposing the negative feed adjustment. If the negative carbon is feeding too fast turn the screw on the negative feed crank to the right. If feeding too slow turn this screw to the left. Do not turn this screw more than one turn at a time. It will require about ten or fifteen minutes' burning to regulate this adjustment, after which the transmission cover should be placed in position and this adjustment need not again be altered unless the arc amperage is changed. While adjusting the negative feed it is essential that the proper arc gap be maintained which is determined by the lines marked positive and negative on the arc cardboard screen. Any change in arc feeds thereafter is accomplished by varying the speed of the motor by means of the potentiometer. The positive and negative hand feed handles are used to accurately position a new carbon trim and also to regulate either or both carbons while they are burning. These hand adjustments should be used while burning in a new carbon trim and also when striking up a cold lamp, rather than frequently changing the automatic feeds.

Focusing the Light Beam

Proper focusing of the light beam on the aperture plate is important and depends on the distance of the reflector from the film, the distance of the mirror from the arc crater, the proper setting of the reflector in its vertical and horizontal swivel to center the light beam on the aperture plate.

The distance of the center of the reflector to the film is 36″. The distance from the arc to the mirror is determined by maintaining the positive carbon coinciding with the arc indicator pin on the positive baffle plate and adjusting the mirror to or from the arc until a well defined spot is obtained

on the aperture of sufficient size to project a clear field of illumination on the screen free from shadows or dark corners. This adjustment of the mirror is accomplished by turning the screw in the center of the rear lamphouse door to the right or left. This adjustment is properly set and locked on all lamps when shipped from the factory and should not be changed unless reflector is changed. To center the light beam on the aperture plate swivel the reflector vertically and horizontally by means of the two adjusting knobs on mirror door.

Proper Burning of the Arc Flame

This is very important and depends on the relative position of the carbons and air drafts in the lamphouse.

The relative height of the carbons is not adjustable as this is properly maintained by the careful construction of the positive and negative holders.

The relative position of the carbons sidewise is made adjustable by moving the entire negative assembly sidewise by the adjusting screw on the left side of the lamp base. On all lamps this adjustment is set at the factory but should it become necessary to change same proceed as follows:

Strike the arc and allow same to burn for several minutes. If the negative flame separates from the positive flame above the positive carbon adjust the negative holder sidewise until the two flames appear as one above the positive carbon. It is not necessary to frequently change this adjustment.

Excessive drafts of air through the lamphouse ventilator will cause the negative flame to rapidly change position. The remedy is to close the damper in the lamphouse chimney until both positive and negative flames burn steady with no apparent influence from air drafts. Crooked burning of the positive carbon crater results in uneven screen illumination and is very often caused by excessive air drafts or improper carbon alignment.

BRENKERT SENARC

Choice of carbon trims permits operation of the "one kilowatt" high-intensity lamp of the Brenkert Light Projection Company of Detroit at as little as 750 watts, which power is said to produce an illumination of 10-foot candles on an average-sized screen.

Known as the Senarc, the lamp is designed to function either with 7-mm. x 6-mm. trim at 40 amperes; or 6-mm. x 5-mm. trim at 30-35 amperes. Light output is rated at 3,300 lumens at the lower current value, and at 4,300 lumens at the higher current.

The lamp is constructed to enable even the smallest theater to project colored prints with true and natural tones of color. Operating costs for current and carbons are said to be from 11-16 cents per hour, according to local conditions.

Compactness, requiring a minimum of space, is achieved by placing the controls along the operating side of the lamp and the carbon feed motor (an external housing) at the front, under the dowser.

New power sources with an efficiency rated at 60% to 70% have been developed for this lamp. They are of three types; rectifiers, constant voltage generator working through a ballast resistor, and double generators of series type needing no ballast. For operation at 30 amperes these sources are said to draw approximately 1,300 watts from the power line, and 1,960 watts from the power line for 40-ampere operation.

The manufacturer points to the comparison of modern high-intensity 45-65 ampere lamps used in larger theatres to produce (at 5,000-6,200 lumens) an intensity of 10-foot candles on a larger screen at an operating cost of 22-32c per hour; and 10-foot candles on a 14-foot screen, at 3,300 lumens, produced by the Senarc at a cost of 11-16c per hour, with the light in both cases of an equal degree of whiteness.

FOREST UNIVERSAL TYPE

Low-wattage high-intensity illumination is afforded by the "universal trim" lamp marketed by the Forest

Manufacturing Corporation of Newark, which is designed to be adaptable, whenever screen size is enlarged to any trim or current that can be used with any mirror-type lamp.

The carbon holders are made to take carbons of any size. Positive and negative carbon feeds are completely independent, using a patented mechanical system which permits the feed rate of any type positive to be adjusted as necessary without affecting the feeding speed of any type of negative carbon.

Forest rectifiers designed for operation with this lamp are correspondingly adjustable to provide current or voltage values required for any type of operation in which the lamp may be used.

The reflector mirror, by Bausch and Lomb, can be shifted by means of adjustable control while the lamp is in operation, to assume maximum optical efficiency at all times. Located behind the mirror is an electromagnet fitted with an adjustable arm, magnetically an extension of the magnet core, which projects under the mirror into the arc chamber proper. This arm can be shifted, altering the distribution of the magnetic field to secure greatest stability of flame under any condition of draft and type of operation.

The carbon holders are constructed to give maximum use of the carbons without necessity of using carbon savers. Automatic stops are provided to prevent burning of the jaws or other injury to them in case too short a carbon should be used. Both positive and negative carbons are guided near the operating point.

SIMPLEX "HIGH"

The intermediate capacity high-intensity Simplex lamp distributed by the National Theatre Supply Company, is rated to deliver approximately 2,000 lumens of white light with operation at 27 volts, 40 amperes. Economy in operation is indicated not only by the low power ("one kilowatt") consumption, but by the slow rate of carbon feed, which is approximately 5.9

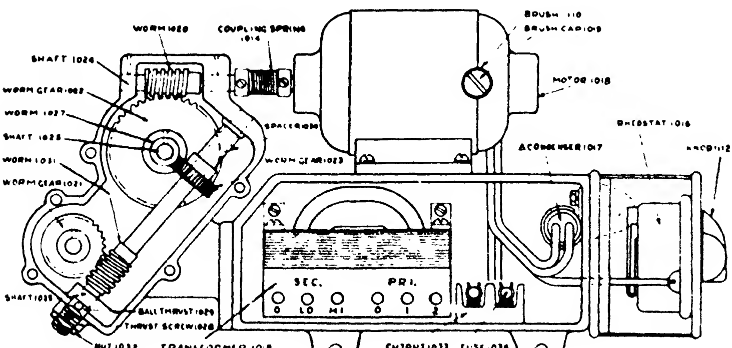
inches per hour for the positive, and 3.75 inches per hour for the negative.

To strike the arc it is only necessary to flip a simply-designed spring controlled contactor. The reflected flame is shown in upright position on a guide card at the top of the housing; it can, of course, also be viewed through dark-glass windows in either side door.

The magnetic field is strongly concentrated in the vicinity of the arc by use of a small ash tray of ferrous metal which is mounted immediately below the arc gap and causes lines of magnetic force to converge upon that location.

Automatic carbon feed is effected without use of relays by means of a specially constructed motor which has a heavy-current control field directly in series with the arc. Lengthening of the arc gap as carbons burn away produces a decrease of current through that field, which in turn speeds up the motor in the same way that decrease of regulating field current speeds up any d. c. motor, and thus causes the carbons to feed faster. As the gap closes, the current through the regulating field grows stronger and the motor speed declines.

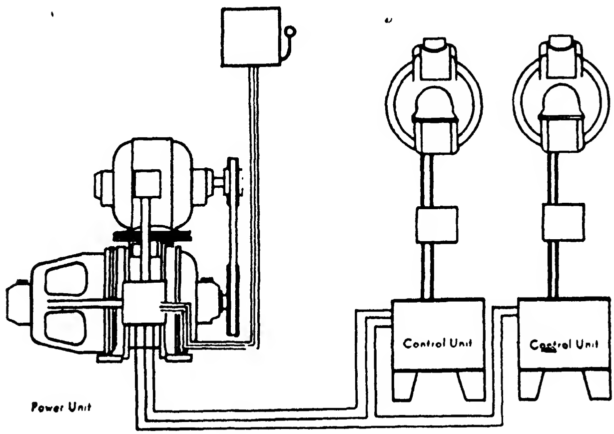
The lamp casing is compactly designed and modernly styled. Controls, except for the dowser controls, are conveniently grouped at the rear. A gap locater and carbon length guide is provided at the bottom of the housing.



CYCLEX

The Power Unit should be located in a well ventilated place, this can be in the projection room, unless local ordinances prohibit this. It may, however, be located away from the projection room as the current supply is low.

The leads from the Control Unit (transformers) to the arc should be kept as short as possible. If they are located in an adjoining room number 4 stranded

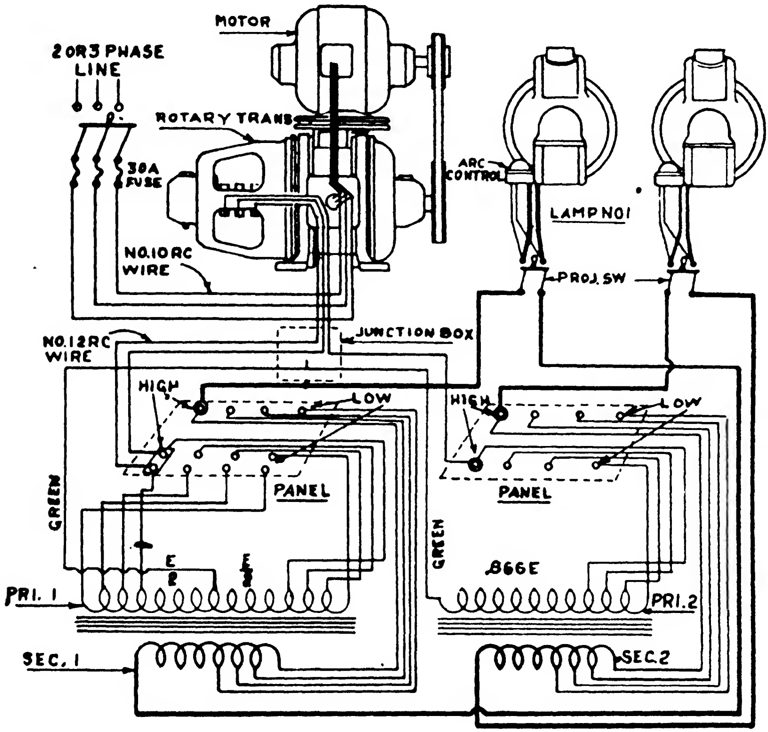


conductors must be used, while if they are located in the projection rooms number 6 stranded cable will be heavy enough.

SETTING UP POWER UNIT

Flexible conduit should be used which may be run under the projecting end of the frequency changer. The junction box contains three pair of wires, the pairs being taped together. These three pairs are to be connected to the line disconnect switch, with number 12 rubber covered wire, all joints to be soldered and taped

Do not use lugs and screws in making connections. The disconnect switch should be equipped with 35 amp. cartridge fuses.

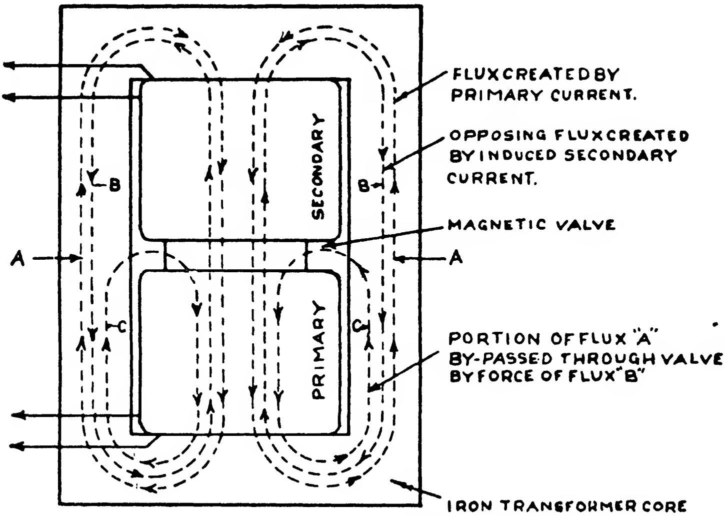


Complete Cyclex Wiring Diagram

A second set of three wires connecting to the rotor brushes will be found in the junction box. Two of these are to be connected to the two back leads of the main transformer, the third to the back wire of the teaser transformer.

The Power Unit should be mounted in a level position so that the rotor will float in the center of its magnetic field. While for the purpose of changing frequency, the power unit may operate in either di-

rection it will be found that in one direction the rotor will float freely, pushing against neither bearing. This



Control Unit Magnetic Valve

may be determined by placing the end of the wrench, supplied for adjusting the variable pitch motor pully, in the countersunk hole in the end of the frequency changer shaft and pushing slightly. If it is found that the rotor is not floating, change the direction by switching two of the three line wires *at the power disconnect switch.* However, do not expect the rotor to float if the Power Unit is not fairly level.

CONNECTING TRANSFORMERS TO PROJECTION SWITCH

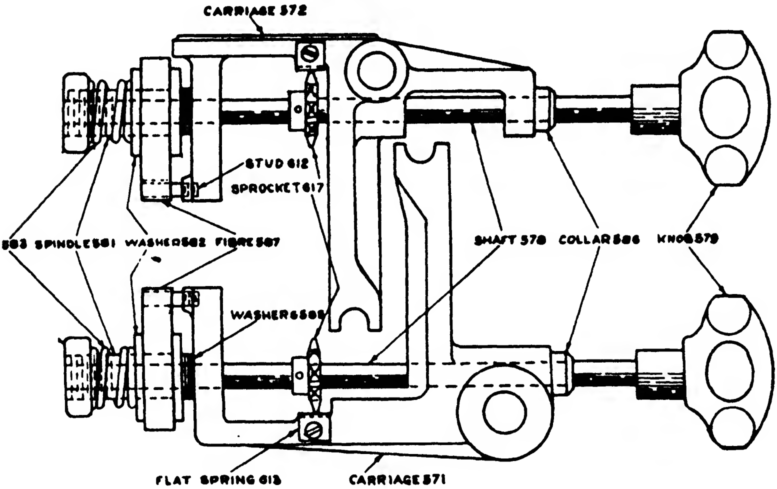
The heavy white leads emerging from the transformers are to be connected to the upper terminals of the projector switch. Be sure that a good electrical contact is made so there will be no heating at this point.

The two lamps should now be set on the projector bases with the edge of the center hole in the mirror 28″ from the film. This distance should not be varied as this distance is such as to produce an aperture spot

of the correct size. Increasing this distance increases the normal diameter of the spot, causing a distinct loss of light, likewise decreasing this distance will result in too small a spot, creating discolored corners and sides to screen image.

LINEUP OF LAMP AND APERTURE

There are several methods for obtaining the proper line-up, the best of which is undoubtedly by means of a straight steel rod which passes through the rear carbon holder, the front carbon guide and the front clamp extending through the lamphouse front to the



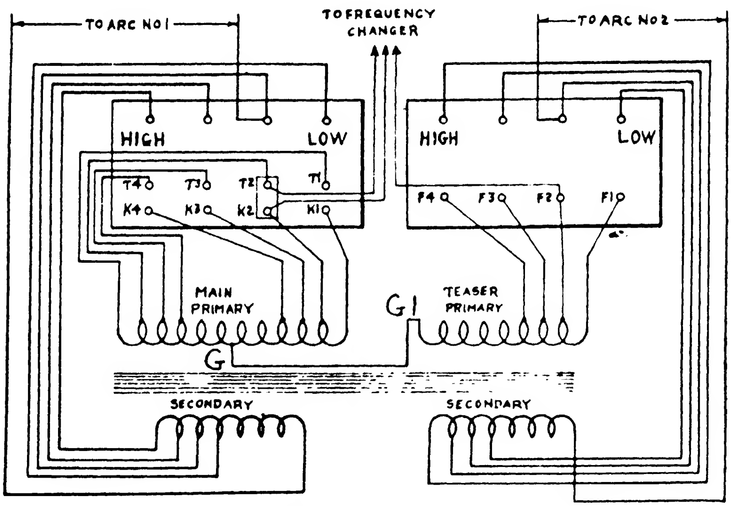
Carbon Carriages and Manual Controls

aperture. Exact alignment may be obtained in this way. However, if such a rod is not available another but less accurate method is to place carbons in the lamp, lining up the two tips end to end. Remove the carbons, without disturbing the position of the carbon holders. Now sight through the rear carbon holder. A light placed behind the aperture will show whether the carbon jaws are centrally located relative to the

aperture.

METHOD OF OBTAINING THE BEST LIGHT UPON SCREEN

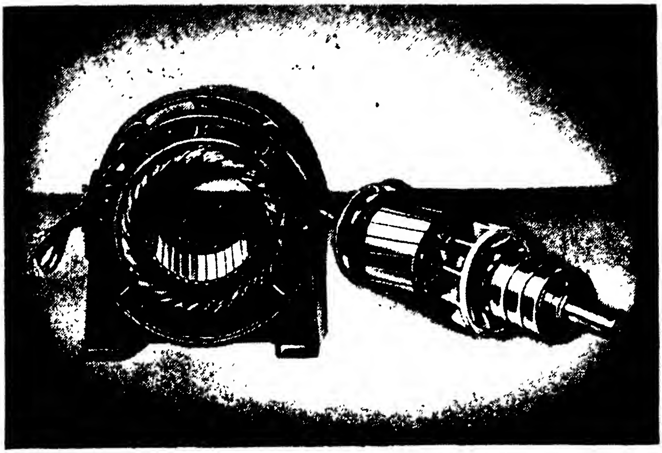
Every optical system has two factors in common—focus and working distance. In Cyclex the working distance is 28″, that is the distance from the edge of the hole in the center of the mirror to the film. The exact focus may vary with different reflections and a slight variation in placing the arc out of the correct focus will be immediately reflected upon the screen. The color of light to be selected should be white not blue nor yellow. Therefore, by grasping the knobs which control the carbons and rotating them the entire



Interconnections of Cyclex control unit

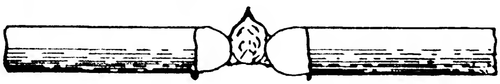
arc (of even arc length) may be moved toward or away from the reflector. This moving of the arc must be done slowly, great care must be taken that the arc length is not altered. When the arc is too far from the reflector the screen light will be blue, when too close it will change to yellow. In between these extremes will be found one position where a brilliant white light occurs. At this point the aperture spot will be of the

correct size to produce a clear field. When this point is reached the arc image (by means of moving the arc scope swivel) should be set on the lines of the guage card. The process of checking the correct position should be repeated several times with each lamp.

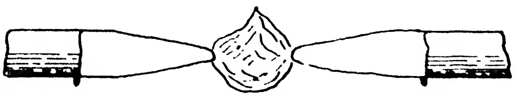


CORRECT CURRENT AND VOLTAGE

There is a definite range of currents within which Cyclex will operate to the best advantage. We advise against any variation from this range as proper results cannot be obtained. Smaller screens (12 to 14 ft.) will naturally not require the illumination necessary with the screens 12 to 19 ft. in width. Therefore, Cyclex provides for a current range of from 52 to 65 amperes. Currents below 52 amperes are not recommended for

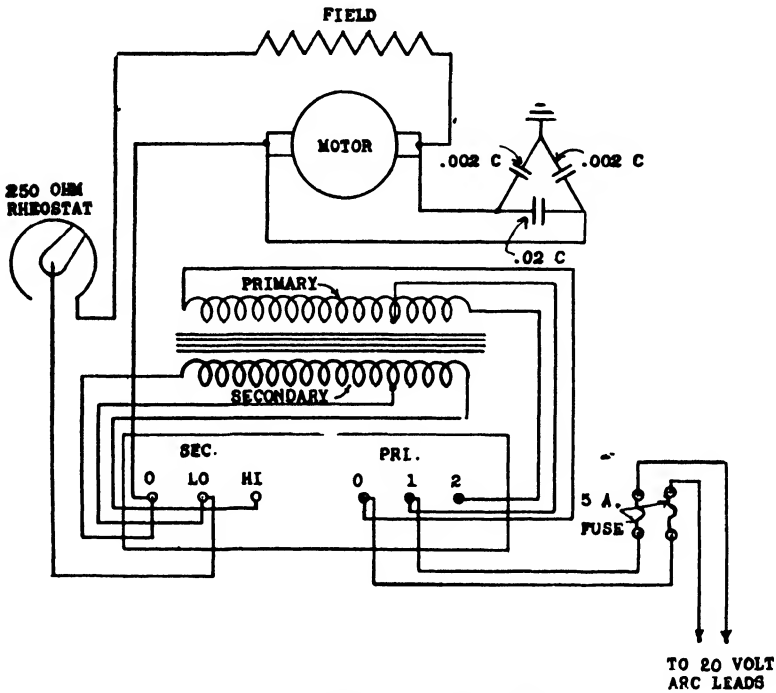


INCORRECT INSUFFICIENT CURRENT.



INCORRECT EXCESSIVE CURRENT.

the reason that below this current value the arc is not stable, having a tendency to shift its position—resulting in color change in the projected light. Currents of the proper value will result in a stable arc of uniform brilliancy.

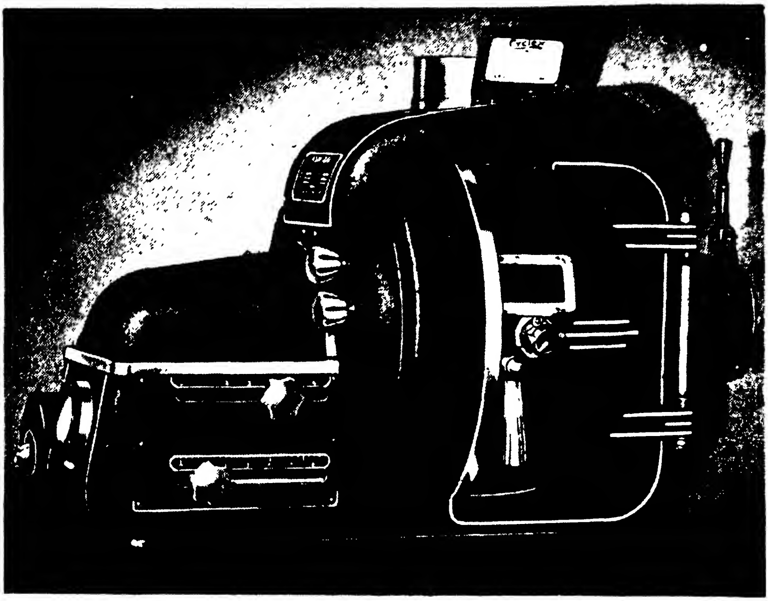


Internal Wiring of Cyclex Arc Control

ARC GAP FOR BEST RESULTS

It has been determined that for maximum efficiency and economy an arc length of 3/16" is ideal. Too short an arc length is not remommended for the reason that the resultant arc is unstable and critical. Too long an arc is wasteful of power and may result in loss of screen light. It follows that there are predetermined arc voltages for various currents. For instance a 55 ampere

arc will have a voltage of about 20 volts, a 60 ampere arc about 21 volts and a 65 ampere arc approximately 22 volts. Optimum screen results are dependent largely upon the correct arc length and voltage as well as the



Cyclex Lamphouse — Operating Side

selection of the proper arc current.

HOW TO DETERMINE WHETHER THE PROPER ARC FREQUENCY IS BEING USED

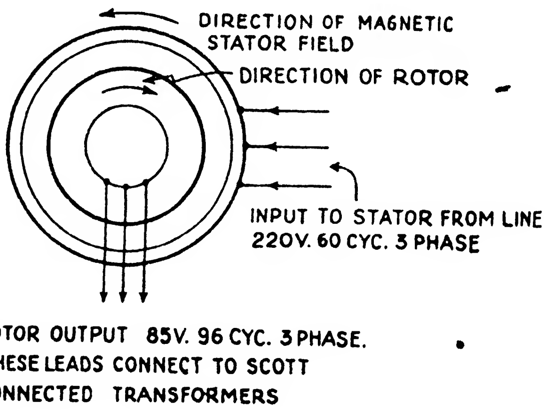
There are many ways of determining whether the arc frequency is in coordination with the speed of the projector shutter, but perhaps the most simple and that which is applicable to all makes of projectors is by the sprocket tooth method. By using the "pull-down" sprocket at the extreme top of the projector mechanism which pulls the film from the upper magazine and maintains the upper loop. By projecting the light from the arc through the machanism and reflecting some of it upon this sprocket it may be de-

termined whether the teeth of this sprocket appear to stand still. If so then the arc frequency and projector mechanism are in synchronism. If the sprocket teeth appear to rotate clockwise then the speed of the frequency changer is too slow, if counterclockwise, too fast.

HOW TO CHANGE THE FREQUENCY OF THE ARC SUPPLY

It is a very simple procedure to adjust the arc frequency to the projector speed. Take off the belt by removing the four screws which secure it to the spider.

The outer flange of the pully on the driving motor shaft has a 1/4" Allen set screw which rests on a flat on the pulley hub. Loosen this set screw, remove the belt and run the outer pulley flange 1/2 turn at a time, counterclockwise to decrease the frequency, setting the screw tightly before each test is made.

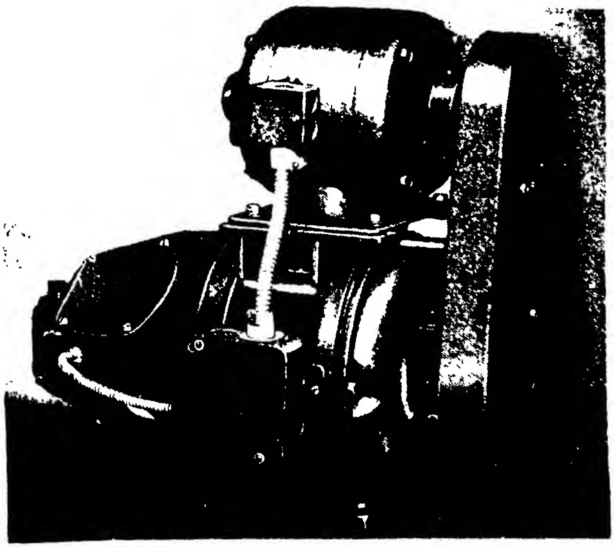


ADJUSTING THE ARC CURRENT ON THE TERMINAL BOARD OF THE CONTROL UNITS

Select the taps nearest the line voltage supplied to your particular theatre, setting the taps of both transformers on the corresponding binding posts. Start with the current taps on "low" (right hand side) and increase by moving the current taps to the left until the

proper value is reached (55 to 65 amps.). If with the current taps on the last binding post to the left sufficient current is not obtained, move the voltage taps on *both* transformers one step to the left. We suggest that at all times the voltage taps be set on identical voltage binding posts but the current taps may be set on any binding post desired. For instance, if the voltage taps on the master transformer are set on 220 volts that of the complimentary transformer should be set on 220, but the secondary taps (current taps) may be set anywhere to obtain a balanced current to both lamps.

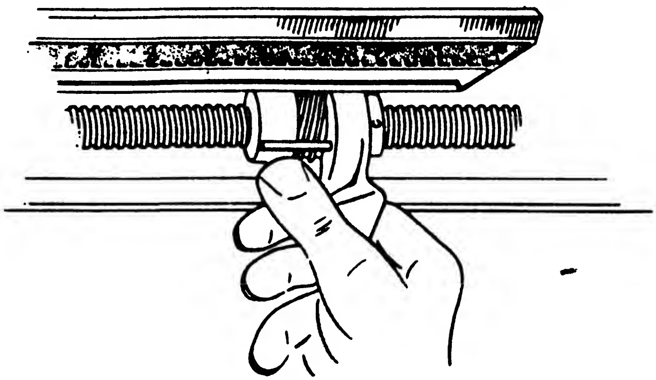
The only adjustment for regulating the arc control is by means of the rheostat knob located on the rear of the arc control. The usual setting of this, under normal operating conditions is on about No. 6 of the dial. Clockwise rotation of this knob increases the speed of the driving motor. It may be found that during the first 20 minutes of operation a slightly higher dial setting may be required, until the motor and rheostat establish a contact temperature after which the knob may be placed on a lower setting. Adjustment thereafter will be necessary.



STRONG UTILITY HIGH INTENSITY

Setting up requires only that the lamp be placed on the lamphouse table and fastened down with the retainer screws. Since the lamphouse overhangs the lamphouse table it is essential that bolts be screwed in the lamphouse front mounting holes to prevent the lamphouse tilting upward.

The position of the lamphouse should be such that the center of the reflector is not less than 29 inches or more than 32 inches from the film aperture; bearing in mind that the 29 inch distance results in most light concentration at the center of the screen with a ten-



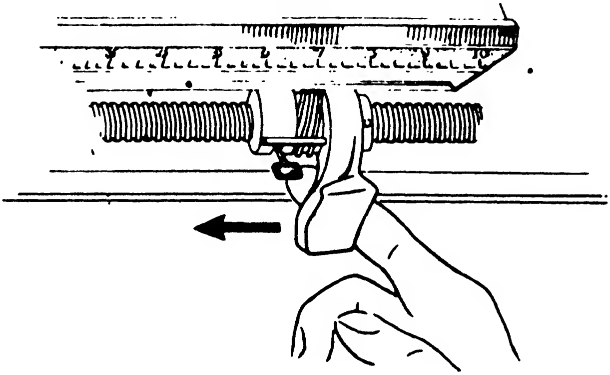
dency to a fall off or discoloration at the corners. As this distance is increased to 32 inches the light distribution to the corners will be improved at the expense of center brilliancy. At some definite point, which is approximately 30 inches from the film aperture, a compromise will be found that affords most ideal screen illumination. The Optical alignment of the lamphouse with the film aperture should be checked by using the aligning rod which is supplied with the equipment.

The electrical connections are marked for polarity. above where the heavy asbestos arc supply wires lead through the rear lamphouse casting. The positive arc supply wire is at the right and this wire has a red colored wire lug. The negative is at the left.

No separate connectors are required for the arc

feeding system as this motor is connected permanently to the arc circuit inside the lamphouse, and this lamphouse comes completely wired.

The trimming light inside the lamphouse is automatically lighted when the lamphouse door is opened. Current for this 25 watt light is supplied by plugging the black duplex cord, leading from the rear of the lamphouse, into any 115 volt convenience supply outlet.



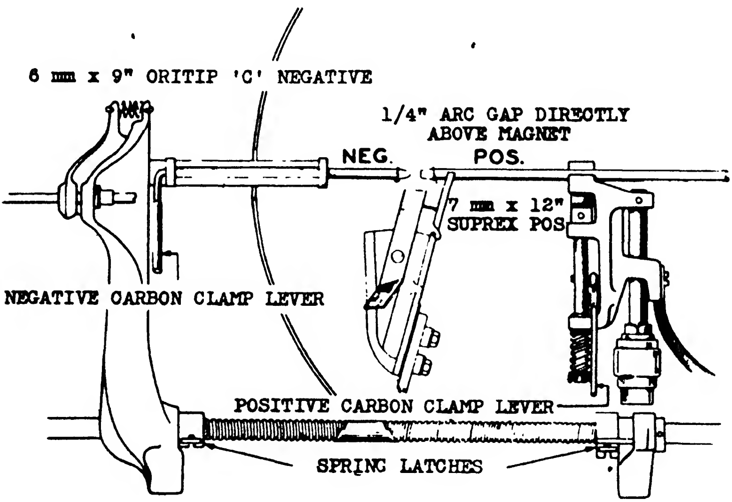
Flexible conduit connections to the pilot light circuit in the lamphouse are made by replacing the porcelain bushing with a one-half inch BX connector. The direct current power supply equipment, whether rectifier or generator, must be of the correct electrical design to assure proper feeding of the carbons. The potential drop across the arc is 27 volts at 40 amperes and the open circuit potential is 32 to 35 volts.

The rectifier is located on the floor directly under the lamphouse. This arrangement is most convenient for the projectionist and permits easy wiring installation.

The A. C. input line to the rectifier, whether single or multi-phase, should be wired through the lamphouse table switch, the switch should be on the power supply line ahead of the rectifier, so that the rectifier tubes are not lighted and the rectifier is "dead" when the arc is not burning. Use at least a No. 8 wire for this power supply circuit.

The direct current or arc circuit must be connected directly from the rectifier to the lamphouse with no switch or fuse in this circuit. Use a No. 6 wire. A three pole knife switch should be installed at the lamphouse table when three-phase rectifiers are used.

Use a 25 ampere fuse for the individual 220 volt single phase rectifier; a 15 ampere fuse for the two-phase, and use 15 amperes per phase for the three-phase rectifier. The direct current circuit from the rectifier



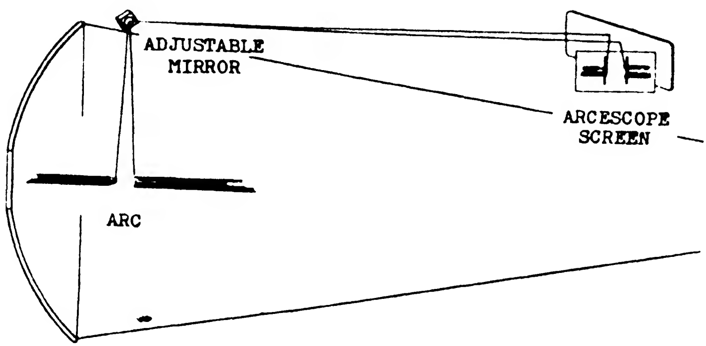
to the lamphouse should not be fused. Ballast rheostats may be used to cut down the output of a 70 or 80 volt generator or power from an 110 volt direct current supply, which is connected through a double-throw switch to supply only emergency direct current power.

Rectifiers or generators of 70 or 80 volts, such as have been used on earlier type arcs, are not suitable as a regular supply to this type arc.

When local conditions require that the rectifier be placed outside the projection room, it becomes necessary to connect a relay in the A. C. power circuit to the rectifier. This relay circuit is energized from any 115 volt, 60 cycle alternating current lighting circuit and connected through the lamphouse table switch with a

No. 14 wire.

A 30 ampere fused knife switch which should be connected to the alternating supply circuit just ahead of each rectifier so that all of the equipment will be dead when the switches are open. The wiring to the generator, where ganerators are used, should be at least No. 8 and the direct current output from the generator to the lamphouse should be at least No. 6. The generator should not be more than fifty feet from the lamp unless a proportionately larger wire is used.



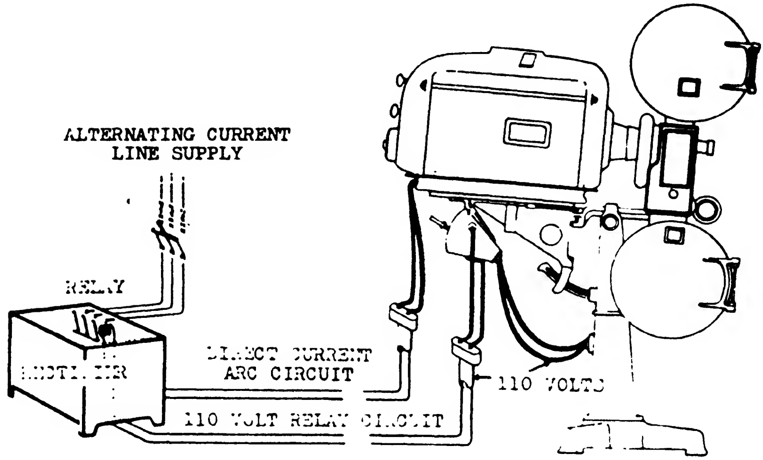
OPERATION OF THE LAMP

To trim the lamp, clamp the 7 m.m. carbon in the positive holder and the 6 m.m. carbon in the negative holder. There should be a 1/4 inch gap between the positive and negative carbon tips and this gap should be directly above the tips of the supplemental magnets. This location of the carbons will assure approximate focus when the arc is first struck.

Before trimming the lamphouse separate the carbon carriages to the limit of their travel along the carbon feed screw and then set the focus adjustment to its mid position.

The knurled focus collar at the rear of the lead screw, should be set at its mid position before trimming the lamp, to assure of ample focus adjustment after the arc has been struck.

Separate the carriages that carry the carbons, to the full length limit of their travel, by depressing their latches with the thumbs of each hand. This downward



pressure will disengage the carriages from the carbon feed screw so that the carriages will slide freely along the carbon feed screw and guide rods.

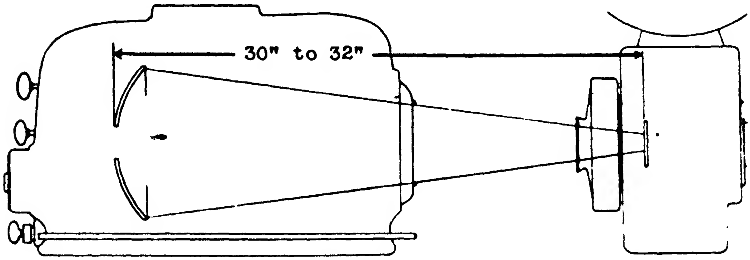
The carbon trim required for this lamp is a 7 m.m. by 12 inches, or a 7 m.m. by 14 inches copper coated high intensity Suprex positive and a 6 m.m. by 9 inches copper coated bored Orotip "C" negative, which carbons burn in horizontal coactional alignment and without rotation.

A 14 inch positive carbon may be used, but this longer carbon will require resetting once to burn the last two inches of the carbon. These longer carbons hardly offer sufficient advantages over the 12 inch trim to warrant their use, because the long lengths are most difficult to manufacture and accordingly cost more per inch and do not burn out quite as economically as the 12 inch trim.

Turn on the electric power by closing the lamphouse table switch, strike the arc by pressing the posi-

tive carriage handle towards the rear of the lamphouse. This will bring the tip of the positive carbon in contact with the negative thus closing the arc circuit. Then release the pressure on the handle permitting the carbons to automatically separate to the proper distance, which establishes the arc.

The arc should be struck quickly to prevent damage to the arc crater and the possible blowing out of the positive carbon core which might deposit a black soot on the surface of the reflector. After the arc has burned two or three minutes or until the arc has settled down and the pointer on the ammeter becomes steady, then manually adjust the arc gap length and the arc focus so that the image of the carbon tips coincides with the lines on the arcescope screen. This will assure a proper arc gap length of 1/4 inch.

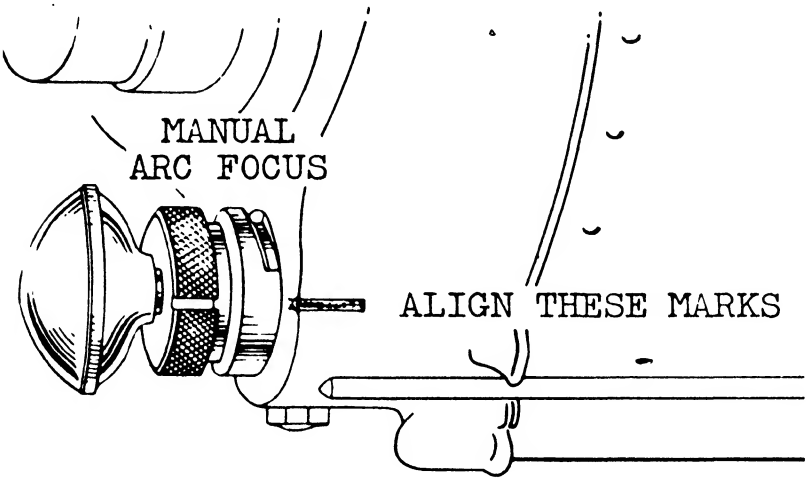


To measure the arc gap length, after the arc has been turned off, it is convenient to use as a gauge, any 6 m.m. negative carbon, which is about 1/4 inch diameter and accordingly should just barely squeeze between the positive and negative carbon tips, when the arc gap length is 1/4 inch.

The preliminary arc current setting to 40 or 41 amperes is by means of the direct current output adjustments on the rectifier or generator, and this adjustment should be made when the arc gap length is exactly 1/4 inch and with the motor control rheostat set at its mid position, which is at points five or six. The arc focus adjustment should be set so that the image of the burning carbon tips fall exactly on the lines of the

arcescope screen.

Then burn the arc for twenty minutes without touching a single manual adjustment on either the lamp or the rectifier and if at the end of this time the images of both burning carbon tips remain exactly on the arescope lines, as originally set, the ammeter is still at 40 or 41 amperes and the arc gap has remained at 1/4 inch, then this first arc adjustment has been correctly made.



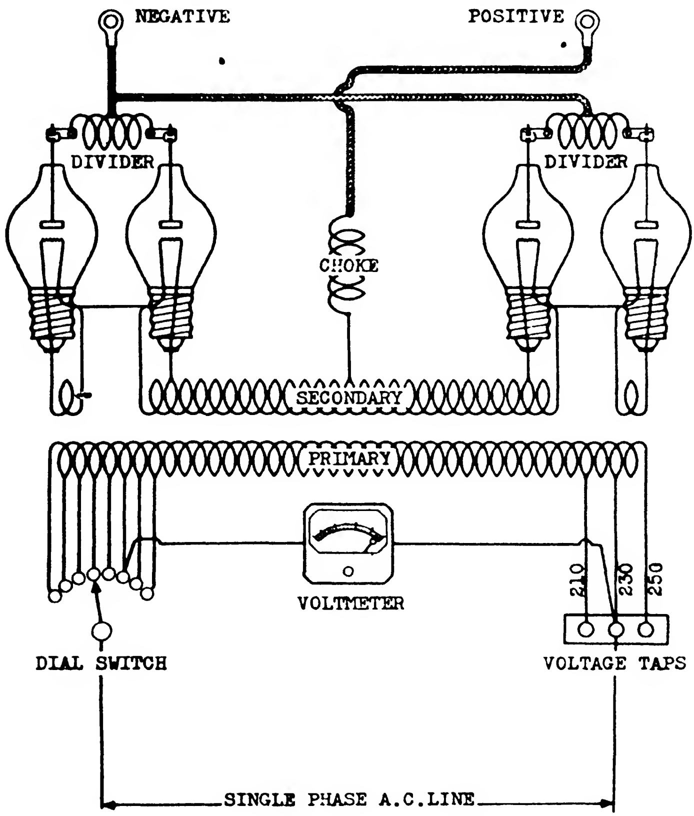
The carbon burning rate is a good indication of general arc behavior and arc amperage: because if the arc current is increased very much above 40 amperes. the burning rate of the positive carbon will increase, so that it will not be possible to project six standard double reels with a single positive carbon.

A Suprex positive carbon 7 m.m. in diameter will consume at 6 inches per hour when burning at 40 to 41 amperes with a 27 to 28 volts across the arc, which is when the arc gap is set at 1/4 inch. This burning rate of 1/10 inch per minute requires 2 inches for each new standard reel of film, which runs about twenty minutes.

One 12 inch positive carbon will burn sufficiently long to project five new standard large reels of film

and allow for lighting up, or burning-in period, and still leave a carbon stub of slightly more than an inch.

The Orotip "C" negative which is 6 m.m. by 9 inches, burns at the rate of $3\frac{1}{2}$ inches per hour or slightly less than 1-3/16 inches per reel. One 9 inch negative carbon will burn two hours and ten minutes, which is sufficient time to project six reels and leave a one and one-half inch stub.



The carbon burning scale on the lamphouse is a convenient means of checking the burning rates of the carbons and in estimating the burning time of the remaining carbon trim.

Focus the arc in relation to the reflector by rotating the knurled manual focus collar until a clear colorless field is secured on the projection screen. Preliminary adjustment of light to the screen may be made while the projector is running, but without film. The final reflector adjustment is best done while a picture is being projected.

Align the witness mark on the knurled focus collar with a similar mark on the rear casting of the lamphouse. This will assure the mid setting of the focus adjustment before the lamp is trimmed with a set of new carbons.

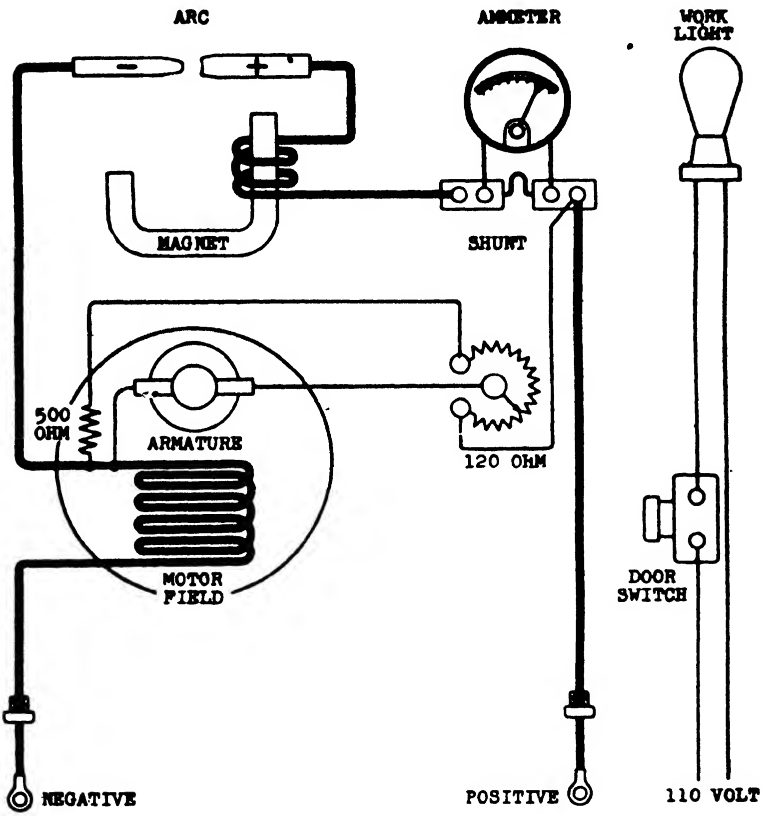
The manual carbon feed is by means of the black moulded knob just back of the knurled focus collar. This knob is at the rear end of the carbon feed screw at the back and lower right hand side and outside the lamphouse. The alignment of the positive carbon requires no attention on the part of the projectionist, since the positive carbon steadyrest is factory adjusted and the positive carbon clamp is full floating to allow for any crookedness in the carbons.

The alignment of the negative carbon tip with the positive must be so that the face of the positive carbon burns perfectly square with the face of the reflector. Both vertical and horizontal alignment of the negative carbon are made by means of the round handles or knobs at the rear and outside the lamphouse.

The hopper which receives the droppings from the arc is removable for cleaning but must not be left out entirely from under the arc, because it supports the supplemental magnets which are essential to the steady burning of the arc. The damper in the stack of the lamphouse should be closed sufficiently to prevent drafts that might disturb the stable burning of the arc.

The Arcescope is an auxiliary optical system which projects an image of the burning carbon tips to a small screen on top of the lamphouse, so that the projectionist may at all times observe the behavior of the arc and make adjustments accordingly. Adjustments of the Arcescope should be made only after the arc and reflector

adjustments have resulted in a clear brilliant projected picture. Then the adjustable mirror should be tilted to bring the image of the burning carbon tips to the black witness lines on the ground glass arcescope screen. Exact arc focus and proper arc gap length are assured after the arcescope has once been set, by simply maintaining the images of the burning carbon tips at these arcescope lines.



The Elliptical reflector is 11 3/8 inches in diameter and has a geometric focus of 4 inches from the arc crater to the center of the reflector and a working distance of 30 inches from the center of the reflector to the film

line. This dimension results in an optical speed of approximately 2.5 to match the speed of the modern projection lenses in use today and as required to project a brilliant picture. The reflector adjustments for vertical and horizontal centering of the spot at the aperture are by means of the two control knobs at top and left: at the back and outside the lamphouse. Cleaning the reflector should be a daily habit, this means actually polishing the reflector every day with a soft cloth to maintain the bright optical surface of the glass. The white scum if allowed to remain on the surface of the reflector soon burns itself into the surface of the glass, then it can only be scoured off by considerable work and trouble. It is best done by using Bon Ami on a slightly dampened cloth.

The pitting of reflectors is a difficulty encountered with all high intensity arcs and is the result of a continuous bombardment by small particles of incandescent carbon projected from the arc crater. This bombardment continues all the time the arc is burning and not only at the time the arc is struck. Carbon particles which may adhere to the surface of an old reflector may be scraped off with a flexible razor blade so that these specks will not hinder the cleaning and polishing of the reflector.

Suppose someone standing on the stage of the theatre strikes a bell, we standing at the back of the auditorium hear a sound. But what makes the sound? Of course the bell must have something to do with it, and if we look at the bell we will see that its sides are vibrating. Is this sound? No, it is only motion, but this motion caused the sound. A little thought will show that the ear, as well as the bell has something to do with the sound; it is with the ear that we "hear" it.

The bell caused the sound, and the ear heard, but how did the ear hear? It is easy to guess that something must have gone from the bell to the ear through the air. For the present let us take it for granted that sound waves traveled from the bell to the ear. The air which carries these sound waves is called a medium.

From this we see that three factors are necessary to sound; first, a cause or origin; second, a medium to carry the sound waves; third, an ear to receive the sound.

At the bell we have a vibrating motion; in the air, nothing but sound waves (set in motion by the motion of the bell); it is not until these sound waves strike upon the ear that there is sound. So, sound is the sensation produced by the action of sound waves upon an ear.

Note the importance of the ear as a factor of sound. The thought may seem a bit odd at first, but it is none the less true that without an ear of some sort present to receive the sound waves, there would be no true sound. It is not a noise which comes traveling through the air when a distant gun is fired, it is not a sound that travels through the air from the stage to the rear of the auditorium when a bell is struck. True enough these things report themselves to an ear as noise or

sound; but to a tree or a building, or to a person without the sense of hearing, they seem to be just what they are, simply disturbances of the air.

Sound has its origin in a vibrating body. In all cases it is not so easy to discover the vibrations, though they are always made. If we clap our hands, the air is set in rapid motion; and it is partly the vibration of the air, partly that of our hands which causes the noise. If a gun is fired, sound is caused by vibration of the air, which is set in motion by the explosion. When one talks, sound waves are made by vibration of the vocal chords in the throat. So with any sound, if we trace it to its origin, we shall find that it started in some body which was vibrating.

How do these vibrations cause sound waves in a medium? Suppose the prong of a tuning fork is made to vibrate, this vibration causes the air immediately around the prong to vibrate and form into waves, each vibration causes a new wave, pushing the old wave out and away from the source of sound, we have seen ripples start and spread out in all directions when a pebble is thrown into a still pond, the sound waves travel in much the same way, spreading out in every direction from their origin.

The whole air does not move forward all the time, any more than does the water of a wave move along with the wave. But as a condensation moves forward, each particle of air hits the one next to it and pushes it on.

When sound waves reach the ear, they hit upon a sort of drumhead, called the "tympanic membrane" causing it to vibrate. This in turn causes other vibrations inside the ear, and finally affect some of the many ends of the "auditory nerve." This nerve goes to the brain. It is the effect of vibrations upon these nerve endings which gives us the sensation of sound.

The exact manner in which the auditory nerve receives these impulses does not concern us at present, it may be said however, that the nerve endings consist of many little rods each one of which is supposed

to respond to a certain sound wave length.

TRANSMISSION OF SOUND WAVES

In general, liquids are better media than gases for the transmission of sound waves, and in general, solids are better media than liquids or gases. The speed with which sound waves travel depends much upon the medium. They will go through water four times faster than through air, and through certain solids like iron sixteen times faster.

Through air at ordinary temperature, sound waves travel about 1125 feet per second; that is, sound waves would go a mile in about five seconds. Light travels at a much faster rate of 186,000 miles per second. This explains why it is, that we see a blow struck, a gun fired or a whistle blown, before we actually hear the sound. It explains also, why there is a pause between the flash of lightning and the report of the thunder, actually both occur at the same time, but it takes the sound waves that much longer to reach our ears after the light waves have reached our eye. If we count the number of seconds that elapses between the flash of lightning and the report of the thunder and then divide this by five (sound waves travel a mile in five seconds) it will tell us approximately how many miles the lightning is away.

The velocity of sound waves depends upon the "elasticity" and the "density" of the medium through which they are passing.

ECHOES AND REVERBERATION

If you throw a rubber ball at a wall so that it strikes the wall at right angles, the ball will come straight back at you, in the same way sound waves strike a wall, or a building, etc., will be reflected back to you in the form of an echo.

The echo will not be as loud as the original sound, because the waves have had further to travel, and some of the sound was lost at the point of reflection. The sound must strike the wall at right angles to obtain an echo.

Sometimes in a large empty hall, we hear a con-

fused rumbling sound after we have spoken or shouted. This is due to the sound waves, which strike the walls and bound back and forth between them. It is like a quick succession of echoes, following each other so closely that they make only a confusion of sounds in the ear. This is known as reverberation.

DIFFERENT KINDS OF SOUND

Musical instruments give off clear and usually pleasing sounds. Such sounds are called "tones" and we know by experience that they are very different from the large class of sounds which we call noises. A tone is smooth and agreeable to hear, while a noise is generally harsh, discordant and unpleasant.

The difference between a tone and noise is simple. A tone is the sound made by a succession of sound waves striking the ear regularly, that is, the length of time between the waves is always equal, as they pass to the ear. A noise is made up of many different sets of waves, some long, some short, all striking the ear at the same time.

Let us show you this a little more clearly. If a single musical instrument were to sound one note, we would call it a tone. The vibrations would be regular, the sound waves would be all alike, and the distance between any two waves would always be the same. If now, a whole band should sound all its instruments together, each player making whatever tone he pleased, the result would not be a tone, but noise. The sound waves would be a mixture of all sorts and sizes and the result on the ear would be a harsh discord.

Tones may differ from each other in three ways, in loudness, in pitch and in quality.

Loudness may apply to all sounds whether tones or noises. Loudness depends on the intensity of the original vibrations, the distance of the ear from the source of the waves, the kind of medium used as a wave carrier, the direction of wind, etc.

The "pitch" of a tone is usually described by the words "high" or "low," "shrill" or "deep." For example we say the pitch of a woman's voice is usually higher

than that of a man's; the call of a bird usually has a high pitch, while the bellow of a bull would be said to have a low pitch. Sometimes the word "key" is used instead of pitch, one might say a tone is "keyed high."

The pitch of a tone depends upon how many sound waves reach the ear in a second; the greater the number the higher the pitch.

It must not be supposed that the human ear can discover all wave impulses in the air. Many of these are either too long, or too short to be heard. The limits of pitch which can be heard by man vary in different persons, and also vary during the lifetime of any one person. Few ears can hear a sound as low as twenty vibrations per second and many persons cannot hear a tone as high as forty thousand vibrations per second.

Now let us see what is meant by the term "quality" of tone.

You have perhaps heard a piano and a cornet sound the same tone; it has exactly the same pitch and may be equally. loud in both cases, yet there is a difference; you would never mistake a piano tone for that of a cornet. Take any two kinds of instruments and try it. No matter if they all do sound the same tone and are all equally loud, you will always pick out a horn, a violin or a banjo. Each sound has its own distinct character, which seems to depend upon the sort of instrument that made it, that is what is meant by the "quality" of an instrument.

We thus see that there are three features of a tone; loudness, pitch and quality.

OVERTONES

A vibrating string may move as a whole and, at the same time, different sections of the string may have a vibration of their own. In fact this not only may occur, but as a general rule it does occur when any string is vibrating, and further, it occurs in most vibrating bodies, whether they be strings, air columns, bells, plates or membranes.

When any such body is causing sound waves, the tone produced by its vibration as a whole is called the "fundamental" tone; any tone produced by the vibration of a section is called an "overtone."

As a rule we do not easily separate the different tones which thus combine when a note is sounded. This is because one of them, usually the fundamental tone, is so much more intense than the others.

In the light of these facts an explanation of "quality" may now be understood. It must be remembered that a sound which does not contain any overtones is very uncommon. The fact that we do not hear them, makes no difference; some overtones are present in nearly every tone, no matter where or how it originated, and it is that presence of these weak overtones which gives to a tone its "quality."

The "frequency" of an overtone is always some multiple of the pitch frequency; that is the second overtone has twice the frequency of the pitch note, and the third overtone, three times the frequency.

Overtones give character and brilliance to music, and their presence in reproduced sound is necessary if naturalness is to be attained. A sound reproducer which reproduces frequencies from 50 to 6,000 cycles will cover all the notes and overtones necessary for natural and distinct sound reproductions.

In singing, the notes range from 80 to 1,200 cycles, but no one person has this entire range.

SOUND FREQUENCY

Any one of a series of variations, starting at one condition and returning to the same condition is called a "cycle."

In electricity we speak of 60 cycle current, this we know is a current that changes its flow of direction sixty times each second, each of these complete changes being one cycle.

If we should fix our attention at some point on the surface of water in which waves exist, we would notice that at one particular point the water will rise and

fall at regular intervals. At the time at which the wave is at its maximum height the water begins to drop, and continues until a trough is formed, when it again raises to its maximum height.

Therefore, if we notice all the variations of height which one point on the surface of the water goes through, in the formation of a wave, we will have witnessed a "cycle" of wave motion.

The number of cycles a wave goes through in a definite interval of time is called "frequency." Therefore the number of times the water rises, or falls, at any one point in one minute would be called the frequency of the waves per minute, and we could express the frequency as a certain number of "cycles" per minute.

In sound, the number of waves per minute is large, and it is more convenient to speak of the frequency of sound waves as the number of waves "per second," or more commonly, as the number of cycles per second.

Thus a sound which is produced by 256 waves a second is called a sound of a frequency of 256 cycles. When speaking of sound, "cycles" always mean cycles per second.

Considered from the standpoint of traveling waves, frequency is determined by the number of complete waves passing a certain definite point in one second, and this of course is equal to the number of vibrations per second generated at the source of sound.

Frequency in wave motion is related to wave-length, the wave length of a water wave is the distance between the crest of one wave and the crest of the next wave. In sound the wave length is determined upon the frequency at the source of sound, a slowly vibrating string will make waves of longer length than will a quickly vibrating string.

If we divide the speed at which sound travels by the frequency we will obtain the wave-length of the sound wave.

RE-ENFORCEMENT OF SOUND WAVES

Other vibrations than those of the body in which they originated often take part in causing sound waves. Some body which is near to or actually touching the vibrating body, may itself be set moving by the influence of the vibrations.

As these motions are the result of the original vibrations they will have just the same rate of movement and give rise to the same sort of sound waves.

Not only do the vibrating bodies produce vibrations in others which they touch, but sound waves may themselves cause vibrations in bodies upon which they strike.

We can hear sounds made out of doors even in a room with all doors and windows closed. The sound waves striking upon one side of a window for instance, cause the glass to vibrate, the moving glass sets up vibrations in the air in the room, and these reach our ear. Of course the waves lose much of their energy in making the solid substance vibrate, so the sound that reaches our ear is not nearly as loud as if the window were open.

FORCED VIBRATIONS

If a common silver table fork or a tuning fork be struck so that the prongs are made to vibrate, a clear tone may be heard if the fork is held close to the ear. If however, after the blow is struck, the handle of the fork is placed on top of an empty cigar box or the top of a table, causing the table or the box to vibrate at the same rate as the fork, the tone may clearly be heard at some distance away.

The reason for this is simple. The vibrations of the prongs are transmitted through the handle to the box or table top, thus causing these to vibrate in unison. In this way a much larger body of air is set in motion by the vibrations of the box or table top, as the vibrating rate is the same, the sound waves made by the table top are added to those made by the fork prongs and thus the sound seems louder.

The vibration of the table top or the cigar box would be called "forced vibrations." The table or the box top having their own rate of vibration; but being made to vibrate by actual contact with the fork, they are "forced" to vibrate at the same rate as the fork.

When any body is made to vibrate by another vibrating body, at a rate not its own, it is said to be in a state of forced vibration.

Examples of this are common. The thin pieces of wood making up the boxes of violins and guitars are thrown into forced vibrations by the movement of the strings. Pianos have a large sounding board back of strings to increase the volume of tone, and the projectionists should be familiar with the use of "baffles" used with loudspeakers.

SYMPATHETIC VIBRATIONS

If we raise the dampers from the strings of a piano and then sing a tone for a moment, the same tone may be heard issuing from the piano. By raising the dampers all the strings are left free to vibrate. As a tone is sounded from outside the piano, the sound waves strike upon all the wires; but they cause vibration only in the one which has the SAME NATURAL RATE of vibration as the body originating them.

When a body which has the same rate of vibration as another is made to vibrate by the influence of vibrations in that other, its vibrations are said to be sympathetic.

This re-enforcement of sound waves by other vibrating bodies is commonly called "resonance." Any device intended to so assist in the production of waves may be called a "resonator."

Let us now briefly review what we have learned on the subject of sound.

Sound has its origin in some vibrating body.

Sound is not sound until it reaches the ear.

Sound waves are employed to carry the sound from its origin to the ear.

Three factors are necessary for sound, a cause or origin, a medium to carry the sound waves, and an ear to receive the sound.

Until the sound waves reach the ear, the waves are just disturbances of the air.

How vibrations set up sound waves.

Sound waves spread out in all directions.

How the human ear "hears."

Sound travels fastest through solids like iron.

Sound travels four times faster through water than through air.

Sound travels about 1125 feet per second through air.

The speed of sound depends upon the "elasticity" and the "density" of the medium through which it travels.

An echo is the reflection of sound, meeting a wall at right angles.

Why an echo is less loud than original sound.

Reverberation is a quick succession of echoes.

The difference between a tone and noise.

How tones differ in three ways, in loudness, pitch and quality.

Pitch depends upon number of sound waves that reach the ear per second.

Overtones are necessary for good music or speech reproduction.

A fundamental tone is caused by vibration of body as a whole.

An overtone is caused by vibration of a section of whole body.

Frequency of overtone is always some multiple of pitch frequency.

Fifty to six thousand cycles covers all notes and overtones necessary for natural sound reproduction.

In singing notes range from 80 to 1,200 cycles.

Number of cycles a wave goes through in a definite interval of time is called frequency.

Frequency in wave motion is related to wave length.

By dividing speed at which sound travels by frequency we will obtain the wave length.

Vibrations other than those in originating body, cause sound waves.

Vibrating bodies produce vibrations in other bodies by touch.

Forced vibrations are those whereby a vibrating body forces another body to vibrate at a vibrating rate not its own.

Re-enforcement of sound waves by other vibrating bodies is called resonance.

ACOUSTICS

The physical wave-motion producing the sound sensation has three characteristic properties; amplitude, frequency and wave-form. The amplitude determines the loudness; the frequency determines pitch; and the wave-form determines the quality or timber of the sound sensation. Loudness and pitch are ordinal properties of amplitude and frequency, respectively. That is, as the amplitude increases the loudness increases; and as the frequency increases the pitch rises.

The relation of loudness to amplitude is not one of a simple direct proportion. For example, the increase in the amplitude of from 10 to 100 produces nearly the same increase in loudness sensation as the increase in the amplitude of from 100 to 1000. This gives rise to a so-called logarithmic relation between sensation and amplitude, and is the basis of expressing the loudness of a sound in the now familiar transmission or sensation unit (T. U. or S. U.) The logarithmic relation between stimulus and response is characteristic of other sense organs. In fact, it is a basic law in psycho-physics, and it therefore plays an important role in all auditory and visual problems.

A somewhat similar logarithmic relation exists between the frequency of the wave-motion and the resultant pitch sensation. This relation is well known. Thus, there is the same interval of pitch between 32 and 64 d. v. (abbreviation for double vibrations per second) that there is between 512 and 1024 d. v. The ratio of the second to the first, in each case, is two, and the musical interval is the octave. In general, equal ratios of frequency correspond to equal intervals of pitch.

LIMITS OF FREQUENCY AND AMPLITUDE

We have stated that the amplitude and frequency of

the sound-producing wave-motion must lie within certain limits. It is of interest to know these limits. The normal ear can sense vibrations in the air which are so feeble as to produce a pressure variation in the air of only one-billionth of atmospheric pressure. These extraordinarily minute pressure variations correspond to movements of the air molecules of only about one-billionth of an inch. The loudest sounds the ear can accommodate have an amplitude of about one million times this amount. Expressed otherwise, the loudest sounds we hear have amplitudes of vibration which are a million times greater than the amplitudes of the feeblest sounds we can hear. This fact has a significant bearing on the problem of the recording and reproducing of sound. For example, the recording and reproducing apparatus must be capable of detecting and transmitting, without distortion, amplitudes of vibration which vary as much as a million-fold. This is a most severe requirement for any physical instrument. Again, these facts indicate the severity of the problem of providing sound-proof stages. It requires careful design and rather elaborate structures to prevent vibrations of so small a magnitude that they will not be detected by the ear or the microphone. Yet this condition is required for the best recording.

The frequency limits of sound also impose serious difficulties in sound recording. The range of frequency to which the ear responds is from 20 to 20,000 d. v. This embraces a range of ten octaves. This range appears quite remarkable when we consider that the eye responds to a single octave. Throughout the ten octaves which the ear appreciates, there is a wide range of sensitivity. The ear is most sensitive for frequencies between about 500 and 5000 d. v., and it becomes relatively insensitive to very low and very high frequencies. These facts also are significant in the design of both sound-recording equipment and sound stages.

A third property of sound is quality. The quality of sound is determined by the shape or wave-form of the vibration. If the sound is produced by the pendular vibrations of a tuning fork, a pure tone is produced. If a musi-

cal note is produced by a vibrating string, the note is what we call rich in harmonics; that is, the note is made up of a harmonic series of simple harmonic vibrations.

The harmonics result from the string vibrating in parts as well as in a whole, and they are responsible for the characteristic quality or tone color of the musical note. For some complex sounds, it is possible to identify as many as forty harmonic vibrations, all blended together to produce the characteristic timber. These harmonics must all be faithfully recorded and reproduced to preserve the natural quality of the original sound.

CONVERSATIONAL SPEECH

Ordinary conversational speech consists of modulated tones and noises. In the production of speech, noises are produced by the larnyx. These noises are modulated and altered by the resonant cavities of the throat, mouth and nose, and the stopping effects of the teeth, lips and tongue. Vowel sounds consist essentially of sustained vibrations. The vibrations first build up to a certain value, then are sustained for a short interval, and then diminish to inaudibility. The frequencies of vowel sounds embrace a range between about 100 and 4,000 d. v. Consants, on the other hand, are not sustained to any great length and they consist essentially of high frequency vibrations. For example, the "s" sound, the "th" sound and the "f" sound are made up essentiallly of vibrations above 2000 d. v. Some consonant sounds require frequencies as high as 7000 d. v. In general for perfect recording and reproduction of speech, a frequency range of about 50 to 7000 d. v. is required.

Music requires even a greater range of frequencies, probably from about 30 to 10,000 d. v. In addition, the amplitude variation is often greater for music than it is for speech. These two factors, together with its greater complexity, contribute to the difficulty of faithful reproduction of music.

In order to give a more definite concept of the extremely minute amounts of energy contained in speech and music some simple calculations and comparsions have been

made. Thus, all of the people in the United States would have to talk continuously for an hour and a half to generate enough heat to make a cup of coffee. Again, it requires 40,000,000 cornets blowing fortissimo to generate one horse power of sound energy. These remarkably small amounts of energy can be transmitted or stored or reproduced only by the most delicate and reliable devices.

CONDITIONS FOR GOOD HEARING

The conditions which must be satisfied for good hearing (or recording) in any interior are as follows:

The shape and size of the enclosure should be such as will provide adequate loudness of speech or music. In general, a small enclosure with reflecting surfaces near the source of the sound will give a louder and more nearly uniform distribution throughout the room. The uniform distribution is greatly to be desired in the recording of sound, since this gives greater freedom in the movement of the source without the "fading" so familiar in current recordings. Reflected sound should be utilized to give a helpful reinforcement of the direct sound.

The walls and ceiling of the enclosure should be arranged and treated so as to eliminate every possibility of echoes. When direct and reflected sounds reach the ear, coming from the same sources but over sound paths which differ in length more than 66 feet, an echo is the result. It is necessary, therefore, to avoid large differences of paths of direct and reflected sound. If very large rooms are designed, all reflecting surfaces which may produce echoes should be well broken up. A curved surface may give troublesome echoes or interference, especiallly if the center of curvature be near the listeners or detectors. Such curved surfaces should be avoided.

EXTRANEOUS NOISES

Extraneous noises, whether of outside or inside origin, should be suitably reduced. Even a slight noise, such as may come from a ventilating fan or from remote outside traffic may impair hearing conditions. There are two

principal methods of construction for the insulation of outside noise: (1) the use of heavy, non-yielding walls and partitions, and (2) the use of multiple layers separated by air spaces. Both methods are in use, and both are effective. All parts of the stage should be consistent with each other. Thus, if the ventilating equipment limits the insulation-value of a stage to 55 T. U. there is little need of going beyond this figure in the design of the walls and ceiling.

CONTROL OF REVERBERATION

The most important factor in the acoustic design of interiors is the proper control of reverberation. At least 90% of the acoustic defects of auditoriums and sound stages are attributable to inadequate control of reverberation. In order to show the effect of reverberation upon the clearness of speech, some speech-articulation tests have been conducted in rooms having different times of reverberation. (The time of reverberation in a room is the time required for a sound to die away to one-millionth of its initial intensity after the source of the sound has been stopped.) These tests show that the distinctness of speech is improved as the time of reverberation is reduced, that is, as more and more absoptive material is added to the room. Thus, the hearing conditions in a room improved from 63% perfect to 93% perfect as the time of reverberation was reduced from 5.0 seconds to .60 second.

REVERBERATION TIME

The optimal time of reverberation for an average sized auditorium, having a volume of 200,000 cubic feet, is about 1.50 seconds. For a smaller room the optimal time is nearer 1.0 second. Experience in radio-broadcasting and in the recording of sound has established somewhat lower times of reverberation for the best preservation of naturalness in reproduced sound. The optimal time of reverberation for recording rooms appears at the present to be about 30% less than the accepted time for auditoriums. Thus, it would seem that about .75 second is the proper time for a small studio having a volume of about 10,000 cubic feet, and that 1.00 second is the proper time for a large studio having

a volume of 200,000 cubic feet.

The time of reverberation is usually referred to a tone of 512 d. v.; that is, the octave of middle C. It is necesary however to obtain a nearly uniform reverberation for tones of all pitch. This is not so easily accomplished because the usual sound-absorptive materials, which are used for reducing the reverberation in rooms, are much more absorptive for the high tones than for the low ones. Thus, most absorptive felts of an inch thickness are nearly five times more absorptive for high pitched tones than for low ones. This means that in a room treated with such material the time of reverberation for low tones is five times as long as the time for high tones. The result is an excessive emphasis and prolongation of all low pitched sound and an excessive damping and lack of resonance of the higher sounds. The bass notes of the horns and viols obliterate the higher and more delicate notes of the violin and piccolo. It is necessary therefore to use absorptive materials which are more uniformly absorptive for tones of all pitch. This calls for very thick absorptive materials, or for multiple layers of absorptive material separated by air spaces. Materials and compositions of materials are being developed to meet this important need.

In general, music requires a somewhat more reverberant space than speech does. It is desirable therefore to make provision for altering, to a small extent, the reverberation of the space in which the recording is done. This can be accomplished fairly satisfactorily by the use of suitable absorptive and reflective materials for the set and flats, but for the best acoustic conditions the entire stage must be appropriately adjusted.

THE DECIBEL

The word "decibel" generally written db, was formed by combining "deci," meaning one-tenth, with "bel" the fundamental unit named in honor of Dr. Alexander Bell, the inventor of the telephone. It meets the need for a unit by means of which one amount of energy, which may be either in the form of electricity or sound, can be compared with another.

In making such a comparison, we could say, for instance, that one energy is twice as great, ten times, a thousand times, or a hundred million times as great as another. Such large numbers are obviously inconvenient to use. For instance, the energy of the loudest sound the human ear can tolerate is greater than the energy of the faintest sound the ear can detect by several million times. A more simple system of working with these large numbers is therefore desirable. The decibel furnishes such a system.

That the human ear is a remarkable mechanism is apparent from these figures. The reason for the peculiar ability of the ear to handle wide ranges of sound energy is that the impression of intensity is, fortunately, not directly proportional to the amount of sound energy reaching the ear. What is meant by this can perhaps best be illustrated by considering two glass tumblers of about the same capacity, one the conventional cylindrical tumbler, and the other shaped like a funnel or an inverted cone. If we fill these tumblers with water a spoonful at a time, the level of the water in the cylindrical one will rise by the same amount each time a spoonful is added. The level of the water in the funnel-shaped tumbler, however, will rise rapidly at first, but as it becomes more nearly filled the increase in level resulting from the addition of a spoonful can scarcely be noticed.

The human ear responds to sound in much the same way as the water level in the funnel-shaped tumbler does to water. As the sound energy is increased in equal amounts, the added sensation of intensity (loudness), resulting from these increases becomes less and less. If, however, each time the sound energy is changed it is increased by the same percentage of its previous value, the result will be increased in the sensation, that is, it will appear to get louder in equal steps. This is indeed a wise provision of nature since it makes the ear sensitive to weak sounds and at the same time protects it from the loud sounds. It is important that this principle be constantly kept in mind, as it will be of con-

siderable aid in obtaining a clear understanding of the subject.

Without going into mathematics of the subject, let us examine the following table of numbers:

Column A	*Column B*	*Column C*
(Ratios)	(Bels)	(Decibels)
1	0	0
10	1	10
100	2	20
1,000	3	30
10,000	4	40
100,000	5	50
1,000,000	6	60

A brief consideration of these figures makes it very evident that there is a definite relation between the figures in these three columns. The figures in Column B obviously represent the number of times the number 10 must be multiplied by itself to give the larger figures shown in Column A. The figures in Column C are ten times the corresponding figures in Column B. Since there is this definite relation between Columns B or C and column A, evidently we can make unnecessary the handling of the large figures shown in Column A, if we work with the figures in Column B or C instead.

If now we consider Columns A, B and C, not as simple figures but as power ratios, bels and decibels, respectively, the relationship involved is apparent. By "power ratio" we mean the number of times the larger of the two powers being compared is greater than the smaller. Thus if we are comparing a power of 2 watts with one of 20 watts, the power ratio is

Aside from avoiding the handling of large numbers, there is another advantage, perhaps even more important, in using bels or decibels in Column B or C instead of the power ratios in Column A.. In combining two power ratios, we must multiply or divide them, whereas the corresponding bels or decibels need only be added or subtracted. For example, if one amplifier

increases the sound energy 100 times and a second amplifier takes the output from the first and increases it 10,000 times, the total increase has been 100 x 10,000 which equals 1,000,000 times. From the table we see that power ratios of 100, 10,000 and 1,000,000 correspond, respectively to 20, 40 and 60 decibels. It is evident therefore that the total increase could have been figured much easier by simply adding the decibels corresponding to 100 and 10,000 (20 plus 40 equals 60) and then referring to Column A for the answer.

Unfortunately, in actual practice power ratios do not often come out round figures such as 100 or 10,000 as used in the example above, they are much more likely to be uneven figures, such as 96 or 9,585. The advantage of using decibels are usually much greater, than would appear from the example given above, and by their use we are enabled to greatly simplify many calculations which would otherwise be very tedious.

There are two principal uses of the decibel

1. To compare one sound intensity to another. For instance, if the energy of one sound is one hundred times as great as another, we say that the first sound is 2 bels, or 20 decibels, greater than the second. Thus, if the output of an amplifier is 6 watts, while the input is .06 watt, a power ratio of $\frac{6}{.06}$ or 100 we say that the amplification, or "gain" of the amplifier is 20 decibels.

2. To measure the absolute value of sound energy by comparing it to some generally accepted standard energy value, either implied or expressed.

For comparison purposes, acoustic experts usually refer sound intensities to "minimum audibility." Minimum audibility, "threshold of hearing," as it is sometimes called, may be defined as the weakest sound which can be heard under absolutely quiet conditions. The power of such a weak sound is unbelievably small, being of the order of only ten thousand millionth of a microwatt (a microwatt is a millionth of a watt),—another indication of the sensitivity of the ear. Thus, when

the acoustic engineer refers to a sound as having an intensity of 50 decibels, the statement is actually incomplete; it should be said that the intensity is "50 db. above minimum audibility," or "50 db. above threshold."

"Minimum audibility" is much too small to be used as a reference intensity for relatively loud sounds, such as those coming from the ordinary loudspeaker. Another reference intensity generally known as the output of an amplifier as being, say, "30 decibels" without specifying that they mean "30 decibels *above zero level.*"

Care should be taken not to confuse the "output level" of the amplifier with the "gain" of the amplifier referred to under (1) above. Each is commonly expressed in decibels, although, as explained, the output level should, strictly speaking, be expressed as "decibels above zero level." Thus, while the *output level* of this amplifier is 30 decibels (above zero level), its *gain* is only 20 decibels as figured above. This will be more readily understood when it is considered that the input (.06 watt) is already 10 decibels above zero level. This is figured from the power ratio of $\frac{.06 \text{ watt}}{\text{zero level}}$ or $\frac{.06}{.006}$ or 10 which, from the table, corresponds to 10 decibels. If the input of 10 decibels above zero level is increased by the 20-decibel gain in the amplifier, the output level will, of course, be 30 decibels above zero level. This is also in accordance with what we said earlier about the addition and subtraction of decibels.

The table given below shows the approximate power ratios corresponding from 1 to 30 decibels. There are two convenient relations to remember in dealing with decibels. The first of these is that ten decibels correspond *exactly* to a tenfold change in power. The second relation to be remembered is that in order to make a sound louder by 3 decibels it is necessary to approximately double its power. What this means can be more easily pictured when you consider that if the Niagara

Power Ratios	Decibels
1.25	1
1.6	2
2.0	3
2.5	4
3.2	5
4.0	6
5.0	7
6.3	8
8.	9
10.	10
100.	20
1,000.	30

Falls power plant output were in the form of sound energy, it would be necessary to construct another power plant of the same capacity in order to increase the sound output by 3 decibels. In the same way for 6 decibels increase, the power would have to be about four times as great, for 9 decibels about eight times as great, and so on.

POWER AMPLIFICATION

We know that the application of an alternating voltage across the grid filament circuit of a vacuum tube will produce in the plate circuit an alternating potential and an alternating current. Also that the process of amplification within the tube results in amplification of voltage. It is possible however to employ the same vacuum tube as a means of amplifying power, that is to convert the voltage fed into the grid circuit into power in the output circuit. Such operation is very desirable in an amplifying system, because many of the devices employed to convert electrical energy into sound via mechanical motion, require power for their operation rather than voltage. The interpretation of power in this case means nothing more than a large value of current in the plate circuit.

Reference to what was said about voltage amplification shows that the magnitude of A.C. current in the plate circuit of a tube used as a voltage amplifier is very little. However when the tube is used as a power amplifier, it is necessary to arrange that the current in the plate circuit be maximum. This suggests that whatever device is connected into the plate circuit be of low resistance or low impedance. This is quite true, but it is also necessary to remember that when current and voltage are present in the circuit, a certain amount of power is dissipated across the tube plate impedance as well as across the external resistance.

Perhaps you wonder at this stage, why it is impossible to utilize most of the power available across the external resistance by making the resistance equal to several times the tube impedance. The reason is founded on the fact that certain devices, particularly loud speakers, require the maximum current for operation and as such make necessary the relation shown. This gives rise to the idea that if Ro is less than "rp,"

the current through Ro will be greater. That is true, but it introduces another factor, the operating characteristic of vacuum tubes. Generally speaking, the impedance in the plate circuit of a vacuum tube must at all times be greater than the tube plate impedance. If it is less, distortion will be the result, a condition which must be avoided in amplification of speech and music. Therefore the optimum condition for maximum power transfer is a state of equal impedances. This is true in all electrical circuits. With respect to tube operation however, it will be found that, that part of the amplifying system employed to operate as a power amplifier, converting voltage input into power in order to actuate a power operated device like a loud speaker, entails an impedance relation where the load impedance is equal to twice the tube plate impedance. The reason for this is that such a condition minimizes distortion, yet enables the transfer of maximum power. In other words maximum undistorted power is transferred from the tube to the load when the load impedance is equal to twice the tube impedance.

We stated that if the voltage input to a voltage amplifier is doubled, the voltage output or the voltage developed across a resistance in the plate circuit of that tube will be doubled. In the power amplifier however, the relation is different. If the input voltage is doubled, the output power is increased four-fold. That is, the power output varies as the square of the input voltage. This explains why certain power tubes do not afford the required power output in audio amplifying systems. The actual reason is that the required voltage input, as stipulated by the tube manufacturer in order that the rated power output be secured, is not applied.

We have observed that a certain voltage and a certain current are present across a resistance located in the plate circuit of an amplifying tube. The magnitude of power across this resistance or impedance, is a matter of the exact value of resistance or impedance used as the load. Hence it is obvious that the difference between power amplification and voltage amplification is nothing more than how the tube is used, with the paramount influence being the character of the load. It is

also evident that a high Mu tube with a high value of plate impedance is unsatisfactory for use as a power amplifier, since the current in the plate circuit is very small. Another important point in connection with the use of a high "mu" tube as a power amplifier is that the output power depends upon the input voltage and since the maximum power output is required, the maximum voltage must be applied. This is impossible with a high "mu" tube, because its characteristics are such that the input voltage is limited because of the low grid bias. Hence the high "mu" tube is not suited for use as a power amplifier. Generally speaking power amplifier tubes are designed to possess a low "mu" and a low value of plate resistance. The low "mu" enables the application of a high grid bias, hence a high signal voltage and the low plate resistance means the greatest current change in the plate circuit. This is the equivalent of saying that power tubes have high values of mutual conductance.

Unfortunately however, the behavior of a vacuum tube is such that best operating condition is not secured with a low external impedance. A low external impedance shortens the length of the straight portion of the characteristic curve and distortion is present when a loud signal is passed through the amplifier. This distortion takes the rôle of harmonics which were not present in the input but which are introduced by the action of the tube and are present in the output. These harmonics change the timbre of the speech or music so that it is not a reproduction of the original. As a point of information, a small amount of harmonic distortion is allowed in an amplifier classed as distortionless, but the extent of the distortion is so small, that is, the intensity of the even harmonics is so low, that it passes unnoticed by the listener. Hence it is impossible to employ an arrangement wherein the maximum power output is secured.

An increase in the value of the load impedance minimizes distortion, but it reduces the power output. Hence it is necessary to strike a compromise of the minimum amount of distortion consistent with maximum output. This condition is secured by making Zo or Ro numerically equal to 2rp.

The vacuum tubes employed in an audio amplifier are arranged to function in a definite manner. All tubes with the exception of the output tubes or those tubes which supply energy to the loudspeaker by means of some form of coupling, are employed as voltage amplifiers in order that the maximum voltage be applied across the grid-filament circuit of the output tube and thus produce the maximum value of output power. It is however necessary to remember that all items possess certain definite operating limitations and the three element tube is no different in this respect. The value of grid bias not only provides the operating axis for the input signal voltage, but definitely limits the value of the input voltage. Further if the plate voltage is increased, the value of the input signal voltage is increased. In addition remembering that the increase in plate voltage reduces the tube plate impedance, it stands to reason that the current fluctuation will be greater for any one input signal, hence the apparent amplification available with the tube is increased.

Considering each item as a whole, it is impossible to increase signal input by increasing the grid bias, because the bias required for a tube is a function of the other operating potentials and the tube structure. Too much bias is as bad as insufficient bias, distortion is the result in both cases. Increasing the signal voltage without correct tube operating potentials which will adapt the tube for the contemplated input voltage or grid swing is also a prolific source of distortion. At this stage, one would ask "Why not boost the plate and grid potentials?" The reasons are quite simple. In the first place, the electronic emission from the filament definitely limits the plate potential. While it is true that the maximum values recommended in tube literature are not the absolute maximum, it is dangerous to increase the plate voltage beyond the stipulated value because the tube elements and the spacing between the elements may not be sufficient to withstand the difference of potential created between the plate and filament, with consequent breakdown.

AMPLIFIER SYSTEMS

AUDIO amplifiers in use today are known under various classifications determined by their function relative to the intensity of the signals passed through them. The form of coupling is very important as regards the placement of an amplifier in a complete system and many complete amplifiers consist of several amplifying units employing different forms of audio frequency coupling.

The form of coupling, that is the method of transferring the energy in one amplifying tube to the succeeding tube, does in many cases influence the position of the amplifier with respect to the entire system because of the special tubes used in conjunction with that form of coupling. Because of the influence of the coupling medium, amplifier circuits are referred to according to the name denoting the form of interstage coupling. No matter what the form of coupling, it is not imperative that a complete amplifier make use of that arrangement. It is possible to employ several forms of coupling in a single multitube system or if so desired by the designer of the amplifier, one form of coupling may prevail through the entire system.

RESISTANCE COUPLING

The simplest yet a very effective method of audio frequency coupling or amplification, and in use in many systems, is that known as resistance coupling. This system involves the use of a fixed resistance in the plate circuit of a vacuum tube, as shown in Fig. 330

The batteries designated as "A," "B" and "C" in each tube circuit are the filament, plate and grid bias batteries respectively. The minus terminals of each B battery are joined thus

making common all battery potentials at this point, and an electric path connecting tubes 1 and 2. While it is not customary in practice to employ individual sources of operating voltage as illustrated, we use this system because we have not reached the stage where it is possible to use common batteries and other sources of potential. E is a source of voltage fed into tube 1. An examination of each circuit shows that each grid filament and plate circuit is complete, the electronic stream within the tube providing an electric path between the filament and grid and the filament and the plate.

We know that an alternating voltage applied at E will cause the flow of alternating current in the plate circuit of that tube. That means that an alternating current will flow through the resistance RL. The operating axis in the grid circuit of tube 1 is provided by the C battery. The B battery provides the required plate potential for tube 1, the steady D.C. plate current flowing through RL. Thus this resistance carries two currents, A.C. due to E and D.C. due to the voltage of battery B. Since current flows through this resistance, two voltage drops are also present across this element. One is A.C. and the other is D.C.

An examination of the diagram shows that one side of the filament circuit of tube 2 is electrically connected through bias

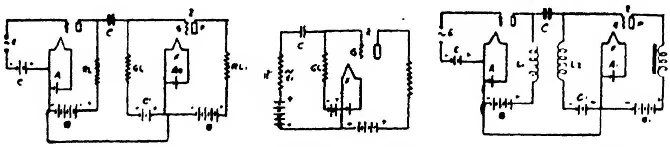


Fig 330 Fig 330A Fig 330B.

battery B, to the resistance RL. This is the common B minus terminal. A further examination of the circuit shows that the grid of tube 2 is also connected across RL, via the condenser C. In other words, we have a circuit such as that shown in Fig. 130A, where tube 2 is actually connected across a source of A.C. such as E1, which in this case is nothing more than the A.C. developed across RL, when the alternating

voltage E is applied to the input circuit of tube 1. Hence RL of tube 1 is a source of A.C. for tube 2. The value of A.C. voltage designated as E1 in Fig. 330 A is equal to that value determined by the formulæ quoted in the chapter devoted to voltage amplification with a resistance load applied to the tube.

Hence the A.C. voltage across RL is applied across the grid filament circuit of tube 2 via the condenser C. It is obvious that the condenser C serves two purposes. First as a means of transferring A.C. voltage to the grid of the tube and second as a means of isolating the grid of tube 2 from the positive potential of battery B which would otherwise be applied to the grid of tube 2 and impair operation of the tube causing great distortion, if not damage to the tube. Thus it is both a coupling condenser as well as an isolating condenser.

The fixed resistance GL is known as the grid leak or grid circuit resistance and likewise serves a definite purpose. If this resistor is removed, a definite D.C. voltage cannot be applied to the grid of the tube in order to set its operating axis. Without the resistance G.L. the grid can assume any value of voltage compatible with the voltage in the grid circuit. Such a condition equivalent to an open grid would cause distortion. To prevent what is known as a "floating grid" the resistance GL is employed as a means of applying the negative bias from battery C1, so as to adjust the operating axis of the grid to conform with the A.C. voltage secured from RL and to provide distortionless amplification within the tube.

Several significant facts are evident in the drawing. First, recalling what was said about the action of condensers in A.C. circuits, a charging current will flow around the condenser C and a voltage drop will be present across its reactance. This drop will then be subtractive from the total voltage secured from RL and less voltage will be applied across the combination GL in parallel with the grid and filament of tube 2. It is therefore necessary to make the reactance of C, by judicious selection of its capacity value, so low that the voltage drop across it is minimum.

The voltage applied to the input of an audio frequency amplifier tube, representing the electrical equivalent of sound

waves, is not of a single frequency, unless such a condition is deliberately desired. Hence the reactance of C will vary with the frequency of E and a variable voltage drop will ensue. If however the reactance of C is low at the lowest frequency encountered in the circuit, satisfactory operation will be secured.

We know that the value of RL must be at least 10 times the plate resistance of tube 1, in order that the maximum A.C. voltage be applied across RL. The reactance value of C must be minimum at the lowest frequency. Furthermore, the reactance of C must be small in comparison with the impedance between GF with the grid leak GL in parallel. Relative to the impedance between GF, the grid and filament of the vacuum tube, these two elements, although small in physical dimension, nevertheless constitute a small condenser possessed of reactance as well as resistance. The presence of a similar capacity between the grid and the plate in a vacuum tube such as the three element structure being considered introduces a coupling between the output circuit of the tube and the input circuit. The extent of this coupling and its effects depend entirely upon the tube constants and the elements connected into the respective circuits, particularly into the plate circuit.

Strange as it may seem, the input tube capacity is really of two values; 1, the static capacity between grid and filament, that is, the element coil without any device connected into the grid or plate circuits, and the effective input capacity when the filament is incandescent and a device is connected into the plate circuit. As it happens the effective input capacity may be several times the static capacity and since this capacity is in shunt with the grid leak GL, it tends to reduce the total impedance of the input circuit, thus reducing the amplification and reflecting back upon the action of RL. This condition is most pronounced upon the upper audio register, that is upon frequencies in excess of 2,000 cycles.

While all of this data is not relative to actual amplifying equipment already in service it is of interest with respect to new equipment or experimental work. Empirical determinations show that three stages of low Mu tubes. give a better

operating characteristic on the high frequencies than three high Mu tubes. On the low frequencies it is necessary to consider the reactance of the condenser C, so that the voltage drop across it is small.

Bearing in mind the fact that as the Mu of the tube increases, the permissible input voltage decreases. When used, the high Mu tube should be nearest to the input voltage where the input is the lowest.

The determination of the voltage ratio possible in a resistance coupled amplifier is interesting and affords a method of determining the value for C, so that as far as the coupling unit is concerned and neglecting the effect of the input tube capacity, a certain ratio of voltage transfer is available over a predetermined audio band. In other words the variation in voltage transfer through the stage should be of a predetermined value, say 10 per cent over a predetermined audio band. The maximum voltage ratio in the stage is secured when the value of C is infinitely large and then is governed by the resistances employed in the coupling unit. The value of C is always finite, hence the maximum voltage ratio is never possible, but is most closely approximate at the high frequencies, when the reactance is low.

The illustration in Fig. 330 shows two amplifying tubes. Each one of these tubes constitutes a stage of amplification. The same method of classification applies to all other forms of coupling as well, but it is necessary to remember that each stage may employ more than one tube. The best method of determining the number of stages in a system is to ascertain the number of complete coupling units in the system, neglecting the device which connects into the first tube but counting the coupling device which links the output tube with whatever is connected to it.

Although the subject of resistance coupling is not wholly completed because there are numerous ramifications of this form of amplification we shall pass onto the next system. However before closing temporarily, the subject of resistance coupled amplification we wish to state, that such amplifiers are usually arranged in sets of two or three stages and are not

limited to operation with battery sources of operating potential but are used with all sorts of devices which supply the required voltages.

In addition, because of the character of the amplifier, it is customary to employ high Mu tubes as the amplifiers, although such an arrangement is by no means compulsory and many resistance coupled systems employ standard amplifying tubes.

Reactance Coupling

Another popular form of radio frequency amplification is reactance of impedance coupling. These terms are applied to signify that the coupling units linking the tubes in the amplifier are coils sometimes designated as choke coils and the amplifier is known as "choke coil coupled."

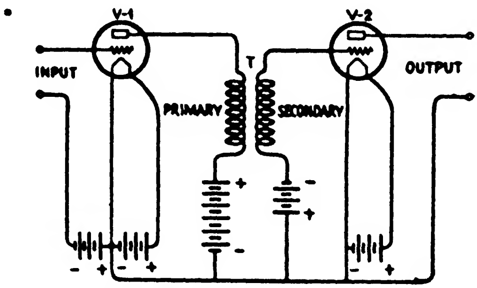
Generally speaking the circuit diagram of a tube system is shown in Fig. 130B. L1 and L2 represents the chokes or inductances, usually referred to as the impedances, in the plate and grid circuits of the amplifying tube. Two such units in conjunction with the isolating condenser C constitute a complete coupling element employed to link two tubes. The similarity between this circuit and that shown in Fig. 130 requires no discussion. The voltage E applied to tube 1 causes an A.C. voltage across L1, which being located in the plate circuit is known as the plate choke. This voltage is then applied across L2 and GF of tube 2. L2 being in the grid circuit of tube 2 is designated as the grid choke. The previously mentioned name is still applicable to the condenser C. It still functions as a coupling and as an isolating condenser.

The position of the inductance L1 and L2 is not standard in all systems. The only thing which is standard is that the inductance values of L1 and L2 are quite high, iron cores being employed, so that good voltage transfer takes place between tube 1 and L1, and that the effect of L2 upon L1 will be minimum on the higher frequencies and so that the impedance of L2 will be with respect to the grid filament impedance of tube 2. Generally speaking L1 and L2 are so located, even when within a single housing that there is not inductive coup-

ling or electromagnetic induction between the coils, the only transfer between the two circuits being that via the coupling condenser C and the return circuit. Such an arrangement makes L1 independent of L2. Such a state is frequently secured by employing two separate inductances contained in two separate housings.

A few words might be of interest in connection with .the usual method of applying such coupling in an audio frequency amplifier. One popular arrangement is to employ tuned impedance coupled amplification. This is arranged in the following manner.

In contrast to the function of C in the resistance coupled system, the variation in resistance of C has very little effect upon the performance of the device. In this system C is a part of a resonant circuit, resonating with L2 and constituting a series resonant circuit. We made mention in the section devoted to series and parallel resonance, that the voltage across the inductance in a series resonant circuit may be many times the original voltage at resonance. This phenomenon is utilized



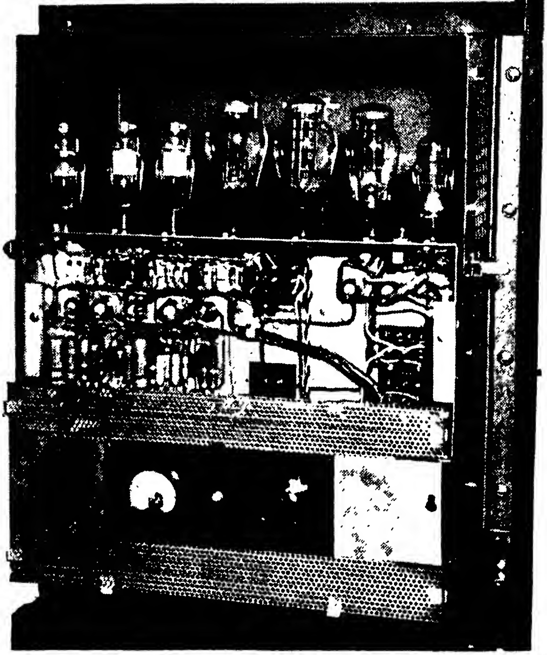
TRANSFORMER COUPLED AMPLIFIER

to good advantage, since the maximum voltage is always desired across L2, inasmuch as the tube is a voltage operated device. Furthermore, the increase in voltage at resonance, affords voltage step-up within the unit at the resonant frequency, despite the fact that the turn ratio between L1 and L2 is 1:1. This voltage step-up at a resonant frequency is made to serve a definite purpose. By setting the resonant frequency at say

some value between 30 and 100 cycles, it is possible to compensate for the low frequency deficiency of the magnetic type of loud speaker, because the amplifier will accentuate at and around the resonant frequency.

Since inductive coupling between L1 and L2 is eliminated and the performance of the system is governed by the L2—C

The TA-7467-A Power Amplifier



circuit, the effect of L1 is neglible, other than to provide the voltage for application across L2—C. Since 90 per cent voltage transfer is available when the external impedance (reactive) is numerically equal to 3 times the tube plate resistance, and since the average choke represented by L1 is rated at from 200 to 1,500 henrys and is used with tubes having plate resistance values between 5,000 and 12,000 ohms, the variation in voltage transfer between the tube and the load over the

normal audio band, between 40 and 10,000 cycles is entirely negligible. Hence for the purpose of analysis we can consider a uniform voltage to be available across the input of L2—C.

The electrical circuit of the tuned double impedance unit as shown in Fig. 330 B is illustrated in Fig. 331 For the sake of simplicity we will imagine pure reactances for L1 and L2, omitting the effective resistance of these two chokes. Their presence influences the magnitude of voltage step-up, but whatever the normal values, voltage increase at resonance is

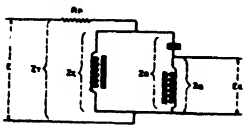


Fig 331

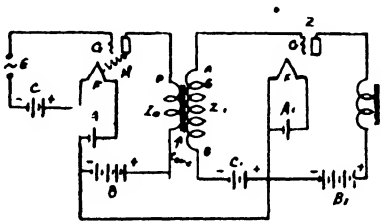


Fig 331A

secured within the coupling unit. E is the voltage available from the tube and applied across the circuit. Rp is the plate resistance of the tube. Eg is the voltage available across the grid choke for application to the grid of the succeeding tube.

As in the case of the resistance coupled arrangement, the system is not limited to one or two stages. Three and four stages may be employed if desired and it is not essential that the complete amplifier be impedance coupled merely because one stage is of that type. It may be combined with any other popular system.

Reactance coupled amplifiers like resistance coupled amplifiers make use of high plate circuit load impedances, hence allow the use of high Mu tubes as voltage amplifiers in the quest for maximum amplification with minimum tubes. One must remember that the higher the amplifying power of a tube, the lower the input grid voltage, unless of course a very high value of plate voltage is employed.

With respect to the amplification available in conventional reactance coupled audio amplifier, assuming that voltage step-

up on a certain frequency is not available in system, the actual amplification is that obtained from the tubes. The inter-stage reactance coupling units do not provide amplification within the coupling unit. The maximum amplification is unity or 1, being the equivalent of transferring the voltage output of tube 1 to the grid circuit of tube 2. If each of these tubes has a Mu of 8, the voltage amplification in the system will be 8 $\times$ 8 or the Mu of tube 1 times the Mu of tube 2. We assume that the full Mu rating of the tubes is being secured, although in actual practice this does not hold true, if the frequency of the voltage input is low. However, because of the fact that the impedance of the average plate load (choke coil) is about 6-10 times the tube impedance, the difference between the secured 95 per cent and the maximum 100 per cent voltage transfer is so small that it is safe to consider the voltage amplification ratio of the tube-coupling unit combination equal to the Mu of the tube.

As in the case of the resistance coupled arrangement, the system is not limited to one or two stages. Three and four stages may be employed if desired and it is not essential that the complete amplifier be impedance coupled merely because one stage is of that type. It may be combined with any other popular system.

Reactance coupled amplifiers like resistance coupled amplifiers make use of high plate circuit load impedances, hence allow the use of high Mu tubes as voltage amplifiers in the quest for maximum amplification with minimum tubes. One must remember that the higher the amplifying power of a tube, the lower the input grid voltage, unless of course a very high value of plate voltage is employed.

Since the voltage produced in the secondary winding because of the action of the primary flux is proportional to the ratio of the turns on the windings, the output voltage of S, the secondary is greater than the voltage input into P, the primary. This means that voltage set-up is secured in the coupling unit. This is in direct contrast to the various coupling devices mentioned thus far, particularly when we realize that this voltage step-up is available at all frequencies passed into the primary.

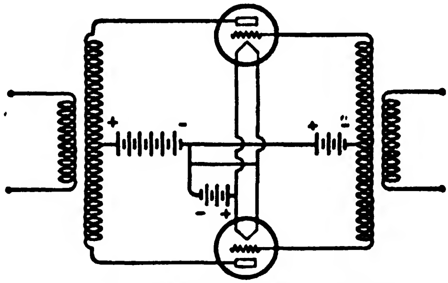
Like the resistance or reactance method of amplification the transformer when employed as a link to audio tubes, operates in a voltage amplifying system. As is evident in Fig. 131A, the primary and secondary windings are individual and apart. The only link between them is electromagnetic induction. Hence it is unnecessary to employ an isolating condenser between the plate end of the primary winding and the grid end of the secondary winding. Since the two coils are not electrically connected, the plate potential applied to the primary cannot find its way to the grid of the second tube unless a defect develops within the unit, whereby the primary and secondary windings come into direct electrical contact.

Realizing that maximum voltage amplification is desired one would imagine that the highest possible turn ratio is employed in the audio unit, just as in the power transformer discussed in a preceding chapter, the turn ratio is based solely upon the output voltage desired. Such however is not the case. While it is true that the turn ratio can be increased to any extent within the breakdown limits of the insulation between the turns and the windings and high voltage step-up would be secured in the transformer, that practice is impossible in a transformer designed for sound amplifying systems. The reason for this is the frequency requirement of the transformer unit. Whereas the power transformer functions upon but one frequency, that of the power supply feeding the input voltage to the primary, the audio frequency transformer must perform over a band of frequencies, representing the full range of all musical instruments and speech. (Qualification of the musical range is necessary because the modern audio transformer will not operate efficiently below C_3, the third octave below middle C, the 32 cycle note.) The requirement of full frequency range introduces complexities into the design, items which are considered of little consequence in the conventional power transformer.

A high turn ratio is not conducive to operation over a large audio frequency band with equal facility. That is, the degree of amplification secured within the unit, despite the fact that the turn ratio is constant at all times, is not the same over the entire band. This condition is due to several reasons, allied

with the electrical design of the unit, and its associated circuits.

Consider for a moment the problem of turn ratio and voltage amplification within the unit. The first specific requirement for an audio frequency transformer is that the impedance of the secondary winding be as high as possible, so that it transfers the maximum voltage across the grid-filament circuit of tube 2.

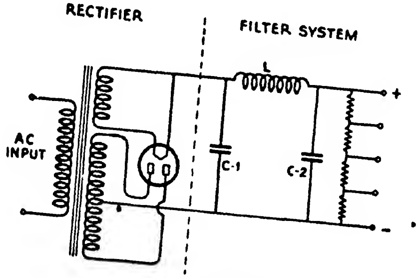


PUSH-PULL POWER AMPLIFIER

The second requirement be that in order that the voltage output of the transformer be maximum that the voltage input be maximum, namely that the transfer of voltage between the plate circuit of tube 1 and the primary of the transformer be as high as possible. This is accomplished by making the impedance of the primary as high as is consistent with design. Thus we have maximum secondary impedance which means inductance and number of turns, and maximum primary impedance which means inductance and number of turns. However, one cannot make the number of turns used in the primary of a huge amount. This is so because a small capacity is present between the individual turns of this winding and between layers of this winding. This capacity is known as the distributed capacity, and is present wherever a number of turns are wound upon a coil. Such a capacity in shunt with the secondary winding would tend to offer a path of low impedance for some of the higher audio frequencies and they would not be applied across the grid-filament of the tube, hence a loss of high notes. Thus we find a definite limitation in the number of turns which may be employed for the secondary winding. It is true that efforts have been made to so wind the secondary

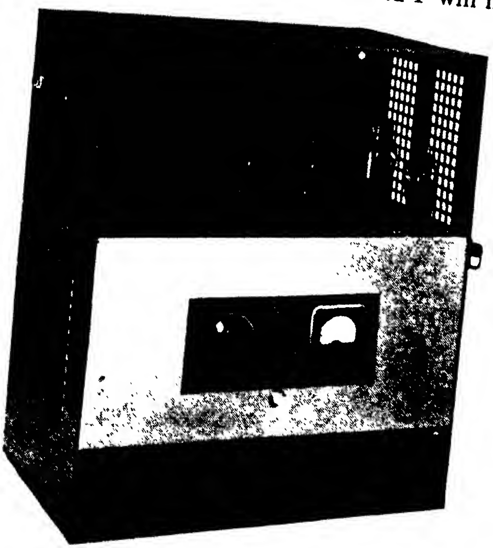
turns that this capacity is minimized, but the limitation is present nevertheless.

With a definite maximum for the number of secondary turns,



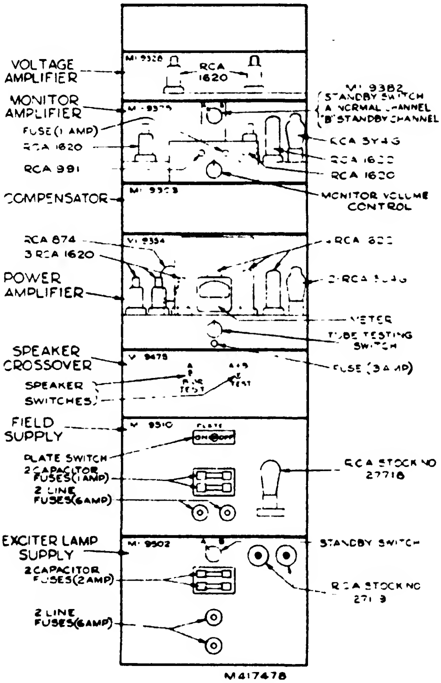
RECTIFIER CIRCUIT

it is logical that if the impedance of the primary is to be as high as possible, that a large number of turns must be used. If this is done, the turn ratio between S and P will not be very



MA-7505-A Amplifier

great and the voltage step-up will not be as great as might be desired. Thus we find a limitation in the primary winding as well as the secondary winding. This is overcome by various means. First. as the acceptance of a definite turn ratio and voltage ratio as being satisfactory. Second is the use of an alloy core instead of silicon steel, whereby a large inductance and impedance are produced in the primary winding with fewer turns.



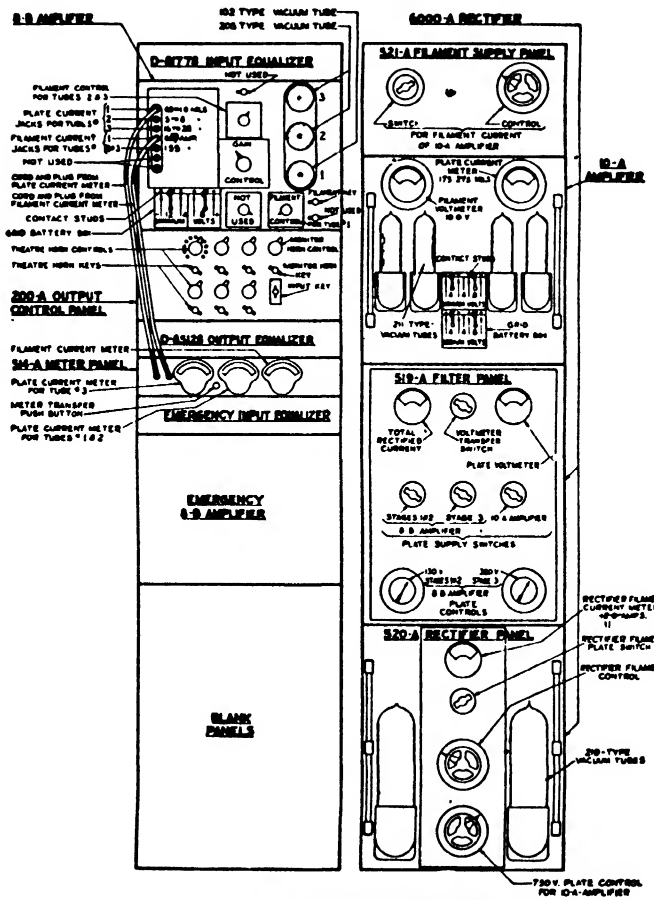
When determining turn ratio, the turns in the secondary remain intact; those in primary being decreased to increase the turn ratio. Each such increase in turn ratio means a reduction in the voltage transferred from the tube to the primary because the impedance relation between the tube plate resistance and the load impedance is impaired. Hence, while the turn ratio of a transformer may be increased from 3 to 6, the

actual voltage output out of the secondary winding when the ratio is 6:1 may be less than when the ratio between the secondary and the primary is 3:1 because a lower voltage is transferred from the tube to the primary of the transformer. The ratio of the modern high quality audio frequency transformer is seldom greater than 3.5:1. In many cases it is as low as 1.5:1.

Another effect that displays a large influence upon the operation of the transformer is that the primary flux does not link with all of the turns of the secondary winding. The greater the turn ratio, the greater is the number of turns of the secondary winding which do not link with the primary flux. Thus we have a leakage of flux. This flux sets up a reactive voltage in either the primary or the secondary. This reactive voltage is the equivalent of a reactance introduced into either the primary circuit or the secondary and the term "leakage inductance" is applied to that portion of the self inductance of the primary or secondary which is due to the leakage of flux. The reactance of this inductance is known as the "leakage reactance." The greater the separation between the turns of the transformer windings the greater the leakage reactance. Now, in actual practice, the distributed capacity of the secondary winding resonates with the leakage inductance or reactance and produces a "peak" in the response curve of the transformer. This peak produces excessive amplification or voltage step-up due to series resonance at the resonant frequency. The lower the ratio of the transformer, the less the value of leakage inductance and since the distributed capacity of the secondary is fixed, the lower the value of L (the leakage inductance in this case) the higher the frequency of resonance. Conversely the higher the turn ratio, the lower this resonant frequency. As a matter of fact such resonant peaks are entirely undesired and modern transformer design is such that the amplitude of this peak or the extent of such undesired voltage step-up is greatly reduced. Wherever possible it is carried beyond the normal audio band, at least beyond 5,000 cycles. Such peaks accentuate signals around that frequency and cause amplitude distortion.

Another detrimental effect of leakage reactance is that the

tube connected to the secondary of the transformer imposes a load upon the winding by virtue of the effect of the coupling device connected into the plate circuit of tube 2. This load alters the action of the secondary winding, changes the leakage reactance and there is a continual shifting of the peak of the

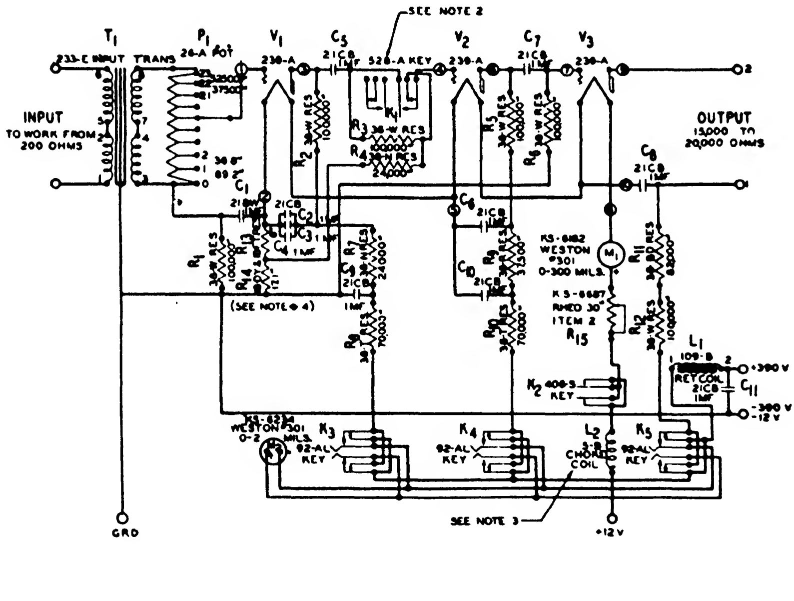


AMPLIFIER AND RECTIFIER EQUIPMENT
WESTERN ELECTRIC SOUND PROJECTOR SYSTEM

transformer and operating characteristic. Such operating characteristics have been very well remedied in the modern radio

systems because of the excellent design of the coupling unit.

Grid current in a transformer coupled system is very harmful. As a matter of fact it is harmful at all times in an amplifying circuit, but particularly so in transformer coupled arrangements. Grid current alters the operating characteristic of the transformer and this action can be well comprehended when one recalls the action of the secondary current upon the primary flux in a power transformer. Grid current is a load upon the transformer with consequent reaction upon the leakage reactance and upon the impedance of the primary of the transformer, changing entirely the operating characteristic and introducing distortion in the transformer as well as in the tube.



COMMERCIAL AMPLIFIERS

WESTERN ELECTRIC AMPLIFIERS

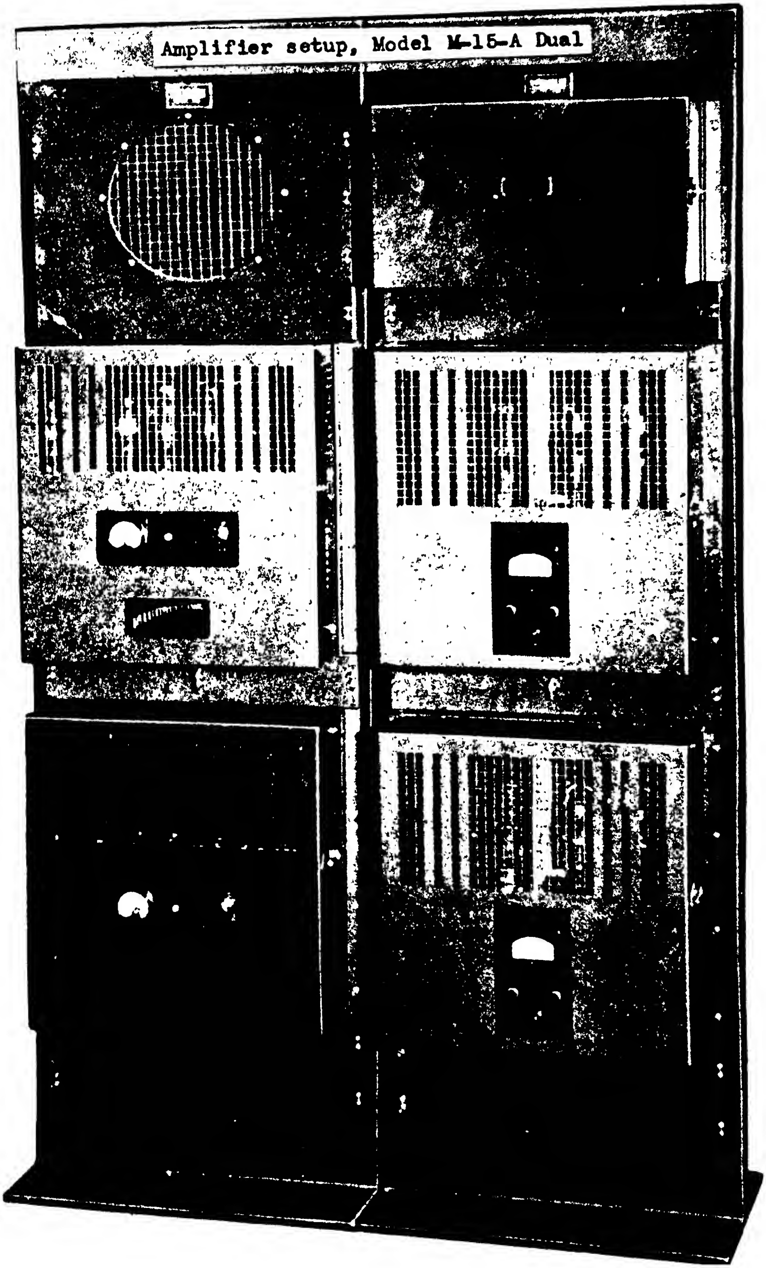
The Western Electric Amplifiers are used in conjunction with the Mirrophonic Sound Systems. The instructions given here for the servicing and maintenance of these amplifiers can in general be applied to almost all other amplifiers used in sound picture work.

THE PA-7505-A AMPLIFIER

This is a chassis-type preamplifier intended for use in motion picture sound systems. Individual input stages for two reproducers ("sound heads") are provided, and these work into a common output stage through a commutator type changeover switch and master volume control potentiometer. The input stages consist of 6SJ7 type vacuum tubes working as pentodes in the usual self-biased circuit. The plate circuits include auxiliary potentiometers to provide facilities for varying the gain of one stage with respect to the other for reproducer output balancing purposes. Coupling condensers are of a specially sealed type having exceptionally high insulating resistance.

The output stage is also a 6SJ7 type vacuum tube, triode connected, and self-biased. Its plate circuit is arranged to supply, via a low-capacity coaxial cable, signal voltage to the associated MA-7505-A Amplifier (in dual type systems, two such amplifiers). A. C. for tube heaters and D. C. for plate and screen circuits and for photocell polarizing currents are obtained from the associated MA-7505-A Amplifier.

The chassis is designed to be mounted in the associated cabinet on one side; tubes and auxiliary balancing controls occupy the opposite, or upper side, and the conventional "bottom" of the chassis faces outward so that all components are easily accessible for tests or servicing. The changeover switch and main volume


Amplifier setup, Model M-15-A Dual

control are mounted on an upright bracket at one corner of the chassis with shafts horizontal so they may be controlled from either projector operating position by means of extension control shafts.

THE MA-7505-A AMPLIFIER

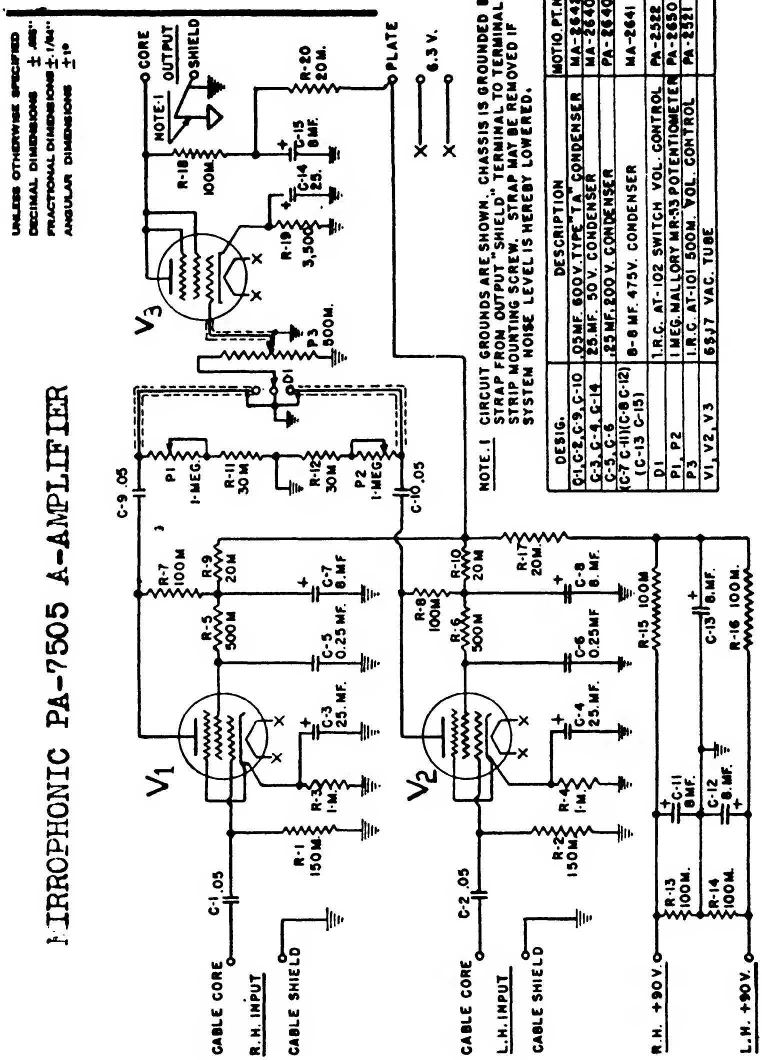
This is also a chassis-type unit intended for use as an output or intermediate power amplifier in motion picture sound systems. The chassis is mounted on one side in the associated cabinet, with tubes occupying the opposite, or upper side. Likewise, the conventional chassis "bottom" faces outward, but in the MA-7505-A Amplifier it is provided with a hinged metal cover plate which thus serves as a front panel, and carries the monitor volume control and the plate current meter and switches. The hinge arms are designed to allow the panel to be swung outward and upward to a rest position exposing the entire interior of the chassis, thus permitting ready access for inspection and servicing.

Electrically, the amplifier consists of a triode connected 6SJ7 type vacuum tube as an input stage driving one of the 6L6 type push-pull output tubes through a resistance-capacity coupling circuit. A suitable proportion of this driving voltage is applied to the grid of another triode connected 6SJ7 type vacuum tube acting as a phase invertor to drive the remaining 6L6 type push-pull output tube via another resistance-capacity circuit.

Separate plate windings for each 6L6 tube are provided in the output transformer so that plate currents may be individually metered for balancing purposes. The transformer secondary provides nominal output impedances of 16 and 32 ohms to permit one, or two amplifiers in parallel, to be directly connected to stage loudspeaker systems of 16 ohms input impedance. An extension of the secondary winding to nominal 500 ohm impedance provides signal voltage, via a grid potentiometer, to an auxiliary 6K6 type vacuum tube operating as a pentode amplifier to serve the associated projection room monitor loudspeaker, which includes the output transformer for this stage.

AMPLIFIER STAGES

All amplifier stages are self-biased. Feedback volt-



NOTE. I CIRCUIT GROUNDS ARE SHOWN. CHASSIS IS GROUNDED BY STRAP FROM OUTPUT "SHIELD" TERMINAL TO TERMINAL STRIP MOUNTING SCREW. STRAP MAY BE REMOVED IF SYSTEM NOISE LEVEL IS HEREBY LOWERED.

DESIG.	DESCRIPTION	MOTIO. PT. NO.
C-1, C-2, C-9, C-10	.05 MF. 600 V. TYPE "TA" CONDENSER	MA-2642
C-3, C-4, C-14	25. MF. 50 V. CONDENSER	MA-2640
C-5, C-6	.25 MF. 200 V. CONDENSER	PA-2640
(C-7 C-11) (C-8 C-12) (C-13 C-15)	8-8 MF. 475 V. CONDENSER	MA-2641
D1	I.R.C. AT-102 SWITCH VOL. CONTROL	PA-2522
P1, P2	1 MEG. MALLORY MR-53 POTENTIOMETER	PA-2650
P3	I.R.C. AT-101 500M. VOL. CONTROL	PA-2521
V1, V2, V3	6SJ7 VAC. TUBE	

age from the output transformer secondary is introduced into the grid circuit of the input tube across its bias resistor to stabilize and improve amplifier performance, and to provide some of the facilities for equalizing the frequency responses of the sound system to suit auditorium acoustical characteristics. The feedback circuit includes for the latter purpose a resistance-capacity network which may be connected in various ways to vary the feedback voltage with respect to frequency, and this in turn causes the amplifier frequency response characteristic to change in an adverse manner as required. Sharp cutoff of the amplifier frequency response beyond the range needed for motion picture service is provided by the rather large capacity across the plates of the 6L6 type tubes in combination with the leakage reactance of the output transformers. Other circuit elements involved in frequency response adjustments include an undersize coupling condenser in the grid circuit of the input tube for reducing low frequency response, and an adjustable resistance-capacity network in its plate circuit for providing various amounts of high frequency attenuation.

POWER CIRCUIT

The amplifier power circuit consists of a heavily filtered choke-input full wave rectifier using a 5Z3 vacuum tube. Except for the input choke, all filter circuits are of the resistance-capacity type, and all major filter condensers, including those in the PA-7505-A Amplifier, are standard double 8 MF, 475 volt units operating well under their rated voltage. The power transformer primary has taps to accommodate line voltages from 105 to 125 volts. The primary circuit includes a switch located on the top of the amplifier chassis for convenience in servicing, and a special fuse block and fuse, with spare fuse holder, to protect the amplifier against overloads caused by tube or other component failures. One low voltage secondary serves the heaters of the MA-7505-A Amplifier tubes, and another is connected to terminals on the main terminal strip for the extension heater circuit to the tubes of the associated

PA-7505-A Amplifier. High voltage D. C. for this amplifier is also provided from the rectifier-filter circuits.

Gain adjustment over a range of 6 db for balancing paralleled MA-7505-A Amplifiers is provided by the multi-unit grid resistance and movable grid lead in the input stage. This adjustment may also be used, in single amplifier systems, to adjust the system gain so that the average recordings will run at a PA-7505-A Amplifier volume control setting near the middle of its range.

OPERATION AND ADJUSTMENT OF AMPLIFIERS

Install vacuum tubes in the amplifiers in accordance with the stamped designations near the tube sockets on the chassis and as called for on the circuit diagrams. Turn the balancing control knobs between input tubes and center tubes and center tube on the PA-7505-A Amplifier to their maximum clockwise rotation (full input stage gain). See that the small switch, D-1, between the 6K6 and 5Z3 tubes on the MA-7505-A Amplifier chassis is in its ON position, and then turn on the A. C. power circuit to the amplifiers. Allow about 30 seconds for tube cathodes to reach operating temperature, and then proceed with the various sound circuit checks. If suitable meters are available, it is advisable to check the voltages being delivered by the MA-7505-A Amplifier at the PA-7505-A Amplifier terminals, and the voltage between the "90 V." and "SH" terminals of the SH-7500 Reproducers. The latter voltages may measure considerably under the rated 90 volts depending upon the internal resistance of the voltmeter used, since they are supplied from amplifier filter circuits incorporating relatively large series resistance.

The milliammeter on the meter panel of the MA-7505-A Amplifier indicates the plate current in the push-pull output stage. The meter normally indicates the sum of the plate currents of the two tubes comprising this stage. When D-2 push button is operated, the plate current of V-3 is bypassed around the meter, and the indication is therefore that of V-3 alone. When D-3 button is operated, the indication is similarly that of

V-4 alone. With both tubes in good condition and with the power transformer primary strap connected to the tap most nearly corresponding to the actual line voltage at the amplifier terminals, the total plate current should be between 150 and 160 milliamperes. Normal current for either tube alone should be 75 to 80 milliamperes. For best amplifier performance, plate currents should be balanced within 10 milliamperes by selection of 6L6 type tubes from those in use and from spares on hand.

Input tubes in the PA-7505-A Amplifier are followed by considerable amplification. It is therefore necessary that tubes for operation in these positions be selected to have the lowest possible microphonic tendencies. Tubes producing low frequency rumbles, clicks, or frying noises when lightly tapped, with main and monitor volume controls well advanced, should be rejected as unsuitable for service.

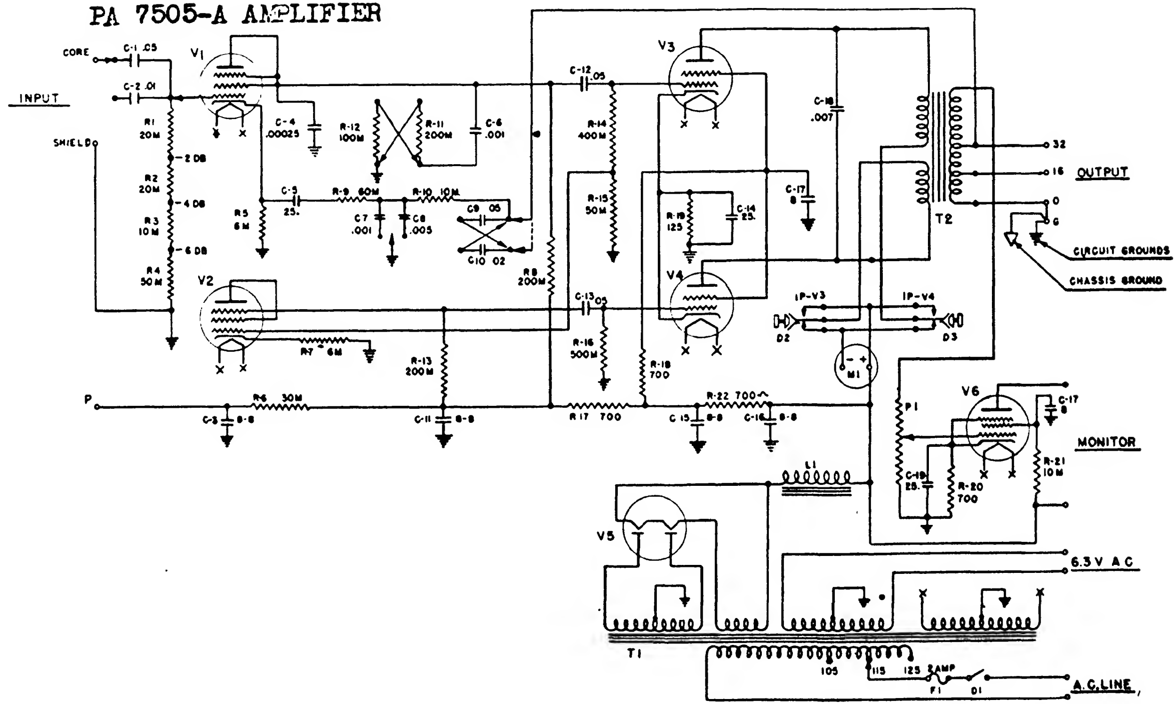
SERVICING OF AMPLIFIERS

The PA and MA-7505-A Amplifiers require little maintenance other than routine testing of tubes, checking of connections, and periodical power output, gain, noise level, and frequency response measurements. Continuous check on the condition of the MA-7505-A Amplifier output tubes and rectifier tubes is afforded by the panel meter and switches. These tubes as well as all other tubes in both amplifiers may be tested in any standard tube testing instrument. As all tubes used for voltage amplification are of the same type, the spare tube problem is considerably simplified.

The changeover switch and main volume control of the PA-7505-A Amplifier are of the commutator type, and require no maintenance so long as operation is positive and noise free. When cleaning becomes necessary, old lubricant and dirt may be taken off with a clean cloth and a solvent such as carbon-tetrachloride, taking care that the contact fingers are not broken off or deformed in the process.

It is suggested that the best maintenance procedure be determined by trial, noting the intervals between required cleanings. In all cases, the dust covers should

PA 7505-A AMPLIFIER



be kept in place since they provide electrostatic shielding as well as protection from dust and dirt accumulation in the interor of the controls.

BY-PASS CONDENSERS AND FILTERS

After long use, electrolytic filters and by-pass condensers may require replacement. Condensers may be checked for capacity, power factor and leakage with suitable testing devices, or by substitution of a unit of the same rating known to be in satisfactory condition.

Intermittently open cathode by-pass condensers are one of the most common causes for unstable amplifier gain. They can be located by observing the magnitude of the gain in db (count volume control steps required to restore gain to normal, and multiply by two), and then, during non-show time, going through the amplifier circuits one by one opening the condenser leads until one producing the same gain change is encountered. Much watching and waiting time can be saved in this manner.

LEAKING CONDENSERS

Leaking plate to grid coupling condensers, often responsible for severe distortion or noise, particularly when the main volume control or changeover switch is operated, are best checked by inserting a mialliammeter in the plate circuit of the following tube and noting whether there is any change in plate current as the condenser circuit is opened and closed. Any change indicates sufficiently low condenser insulation resistance to warrant replacement. As has been noted, all plate-grid coupling condensers in 7505-A type amplifiers are of a specially insulated and sealed type having over 1500 megohms insulation resistance.

W. E. TA-7466-A AMPLIFIER

The TA-7466-A Amplifier is a chassis-type preamplifier, also providing facilities for volume control of, and sound changeover between two suitable inputs; for example, two SH-7500 Reproducers. Electrically it consists of a single stage of amplification for each in-

put, working into a common output stage through individual volume controls and a changeover switch. The input stages consist of 310-B Vacuum Tubes working as pentodes in the usual self-biased circuit. The output stage consists of a single 310-B Vacuum Tube connected as a triode by strapping the screen grid to the plate. Its cathode resistor is not by-passed, and negative feedback is thereby introduced.

INSTALLATION

The TA-7466-A Amplifier is intended to be mounted in a suitable housing such as the PA-7500 Control Cabinet, or a PA-7015 Amplifier Cabinet, mounted between the two projectors on the projection room front wall. These housings usually have as associated apparatus a set of extension rods, couplings, and knobs for extending the changeover switch and right hand input volume control to the right hand projector operating location.

Mount the TA-7466-A Amplifier in the PA-7500 Control Cabinet, or in the PA-7015 Amplifier Cabinet, if it is not received mounted. Make connections to its terminals in accordance with the sound system connection diagram.

TESTING

Although routine testing will not require that any readings be taken at the output of the TA-7466-A Amplifier, it will be useful to know the proper method of connecting a volume indicator meter.

(a) Connect the meter between ground and the junction of C-1 and R-1 of the ascociated TA-7466-A Amplifier.

(b) Connect the meter to the output terminals of the TA-7466-A Amplifier with a 0.05 mfd or greater capacity condenser in series with the high side.

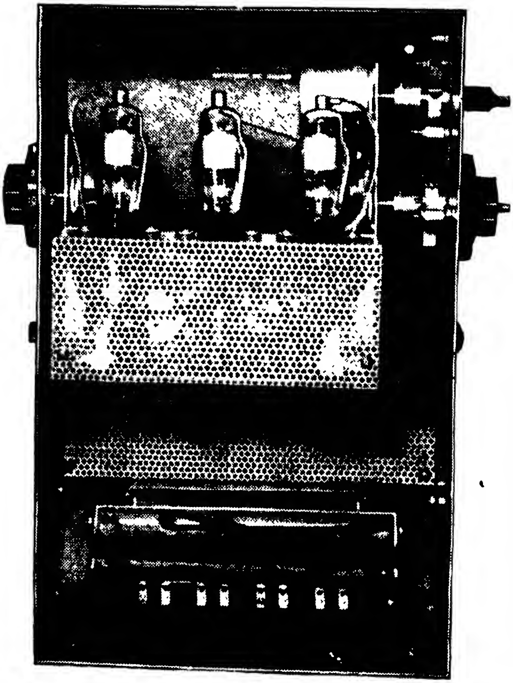
(c) Output terminals of the TA-7466-A Amplifier, and input terminals of the TA-7467-A Amplifier are at 230 volts potential with respect to ground.

(d) Operate TA-7466-A Amplifier volume controls to minimum value before connecting or discon-

necting volume indicator meter to prevent excessive surges to stage speakers.

SERVICING

Periodically check all connections,, resistors and condensers for satisfactory condition by tapping units



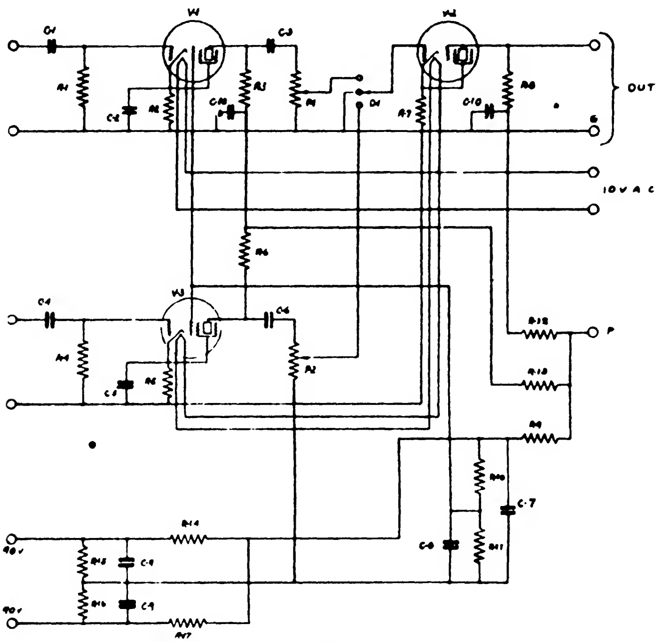
Western Electric TA-7466-A Preamplifier

with an insulated rod while volume controls are at miximum setting. Do not clean volume controls and changeover switch unless noisy operation or poor contact occurs. Keep dust covers in place. If cleaning becomes necessary use fine sandpaper (00 or finer) and after cleaning, thoroughly blow out all dust and grit. Lubricate contacts and bearing surfaces very lightly with a good grade of clock oil.

Adjust cast stop lugs on extension control rods so that all stopping strain is taken by the lugs rather than

by lighter parts inside volume control and changeover switch.

After long use the various electrolytic filter and by-pass condensers may require replacement. Condensers may be checked by measurement with a suitable testing device, or by substitution of a unit of the same rating known to be in satisfactory condition.



MIRROPHONIC ----TA-7466-A Amplifier

W. E. TA-7467-A AMPLIFIER

This is a three stage resistance coupled amplifier. The first stage is a type 310-B pentode coupled directly to the pre-amplifier. A slight change in low frequency response may be obtained by connecting one or both of the grid coupling condensers, C-1 and C-2, in circuit. A tapped grid leak provides for a change of 10 db in overall gain. A rise in the high frequency response is produced by variable feedback in the screen circuit (R-18, C-15). A high frequency drop is produced by

shunt condensers C-6 between the first and second stages and C-9 between second and third stages. A low frequency rise is accomplished by the shunt circuit consisting of C-5, C-7 and R-6. The amount of the rise is determined by connecting one or both of the condensers or by short-circuiting them.

The second stage of the main amplifier consists of a 310-B pentode (V2) and a 310-B tube connected as a triode (V3) used as an inverter stage. Each of those tubes is self-biased without a by-pass condenser, thereby introducing negative feedback. Feedback is also introduced from the output transformer to the cathode of the 310-B pentode (V2). The third stage consists of two 300-B Vacuum Tubes in push-pull. An output impedance of 12 ohms or 24 ohms is available for direct connection to the loudspeaker or dividing networks. An additional output winding is connected to a 336-A pentode (V7) for driving the monitor loudspeaker. Monitor volume control is obtained by means of a grid potentiometer. The output transformer is mounted with the TA-7472 Monitor Loudspeaker.

A choke coupled rectifier circuit employing a 274-A tube (V6) is used. The voltage across R-24 provides a suitable bias between the heaters and cathodes of the pre-amplifier tubes in order to reduce the hum level. The meter is of the 100% (of normal) type with resistors in the plate circuits. The resistors are so located in order to avoid effect on the feedback circuit; which would be the case if they were located in the cathode to ground circuit.

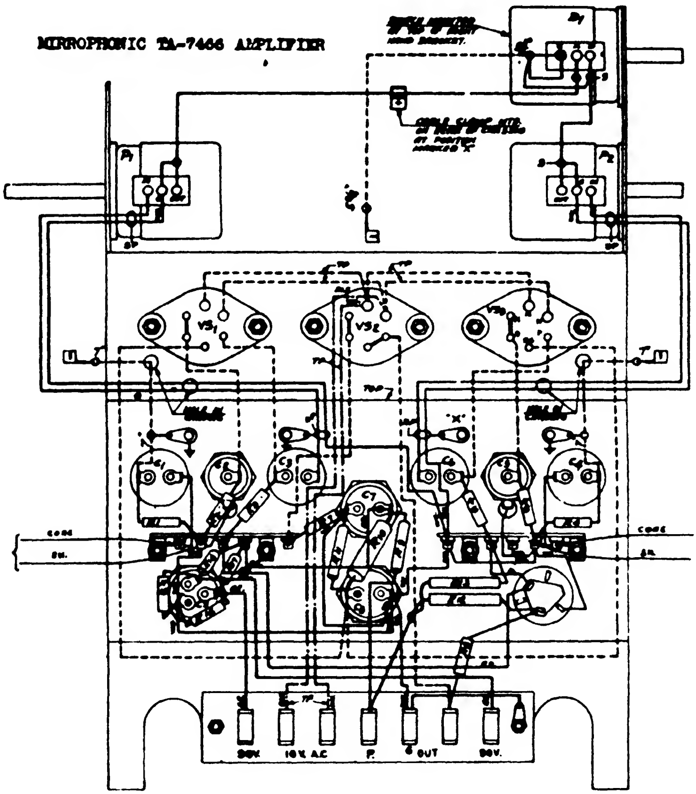
All the vacuum tubes are mounted on the top side of the chassis. In this way, the wiring is immediately available without moving the chassis from its normal position which is with the open side to the front of the cabinet. The meter, switch and monitor volume control are located on a small panel on the open side or front of the amplifier.

Volume control (10 db) may be obtained by varying a resistance (20,000 ohms) in series with the cathode resistor by-pass condenser which varies the in-

ternal negative feedback. This variable resistor for volume control may be located in the auditorium or elsewhere at a moderate distance.

OPERATING AND TESTING

Turn the amplifier system on or off at the main power switch for the sound system. The small switch on the amplifier chassis is intended only for convenience during testing or replacing tubes.



Normal amplifier operation and satisfactory tube condition is indicated by readings on the panel milliammeter varying not more than plus or minus 25% from the mid-scale or 100% mark. The switch adjacent to the meter (use a coin to operate it) permits the

meter to be connected to indicate the plate current in any one of the five main amplifier tubes (monitor amplifier plate current is not metered). The plate current indications in switch positions 2 and 3 should not differ by more than 15% for proper operation of the phase inverter stage comprising these two tubes. Plate currents of the two 300-B tubes (switch positions 4 and 5) should not differ by more than 25% for normal amplifier output harmonic content. Under certain line voltage conditions the plate current of V-1 may be considerably above 125% without effect on amplifier performance. The 310-B tubes in the TA-7466-A Amplifier may be checked by temporarily installing them in VS-1, VS-2, or VS-3 sockets.

The overall electrical frequency response of the reproducer and amplifier system may be taken using a standard frequency film for excitation and a suitable volume indicator meter at the amplifier output. In such measurements it is customary to replace the loudspeaker load with a fixed, non-inductive resistance of the same value as the nominal load impedance. If the loudspeaker dividing network does not provide facilities for this purpose, disconnect the ungrounded side (12 or 24 ohm) of the output circuit at the amplifier terminal strip. Connect a 12 ohm or 24 ohm fixed resistance from the appropriate output terminal to the "O" terminal, and connect the volume indicator meter across this resistance. Most volume indicators, or output, meters are calibrated to read correctly in db when connected to a 500 ohm circuit. When such a meter is connected across a 12 ohm circuit a correction factor of 16.2 db must be added to the meter indication to get the true power level. For a 24 ohm circuit the correction factor is 13.2 db. In taking the system frequency response the volume control should be adjusted so that at no frequency will the sum of the correction factor and the meter indication exceed 34 db, the maximum rated power output of the TA-7467-A Amplifier.

SIMPLEX AMPLIFIERS

The AM-1001 is an all A.C. operated two-stage, inverse feed-back, resistance coupled, push-pull amplifier weighing 30 lbs. Two terminal strips on extension cable forms are provided for external connections. Maximum gain 60 db., input impedance is 10,000 ohms, output impedance is 12 or 24 ohms, output is 15 watts, the maximum noise level minus 35 db. Gain control potentiometer (range 12 db) is adjustable from the front of the panel by means of a screw driver. A warping circuit is provided in the inverse feed-back circuit which may be adjusted to increase or decrease the high and low end response to compensate for varying acoustic conditions in auditoriums.

Heater and plate supply for the volume control amplifiers and the monitor amplifier are provided by a voltage divider. On the panel are an AC switch, a tube testing switch, and a meter with a special scale to indicate directly the condition of the tubes.

Power supply required is 100-130 volts AC., 50-60 cycle. Power consumption is 115 watts. Fused with 2 ampere Fusetrons.

INSTALLATION OF AMPLIFIER

The AM-1001 should be installed in the AM-2023 Cabinet in the location as shown on the conduit layout drawings. Connections should be made to the terminal strips according to the wiring diagram. Power transformer connections and Output Transformer connections should be made in accordance with the data supplied with the equipment.

When only one amplifier operates at a time, this resistor (R-3, 2000 ohms) should be strapped out. When two amplifiers normally operate in parallel, the strap (red jumper from R3 to R8) should be removed in each amplifier to maintain a constant impedance.

When four amplifiers normally operate in parallel, the R2 resistor should be replaced by the 8000 ohm resistor, to maintain constant impedance. No wiring changes are necessary.

STRAP BETWEEN TERMINALS "RVC 3" AND "RVC 4"

When only one amplifier operates at a time, this strap should be connected. When two or more amplifiers operate in parallel, disconnect this strap, as the amplifier switch supplied in such cases, makes the necessary connections to these terminals.

GAIN CONTROL

The gain control of each amplifier in the system should have the same setting, and be adjusted to obtain adequate volume level in the specific theater. Counter-clockwise rotation increases the volume. The setting should be as low as possible, and never in the extreme counter-clockwise position. Thereafter, no adjustment of this control should be necessary as the main volume control in the AM-101 should be used to compensate for variations in prints, size of audience, etc.

VACUUM TUBES

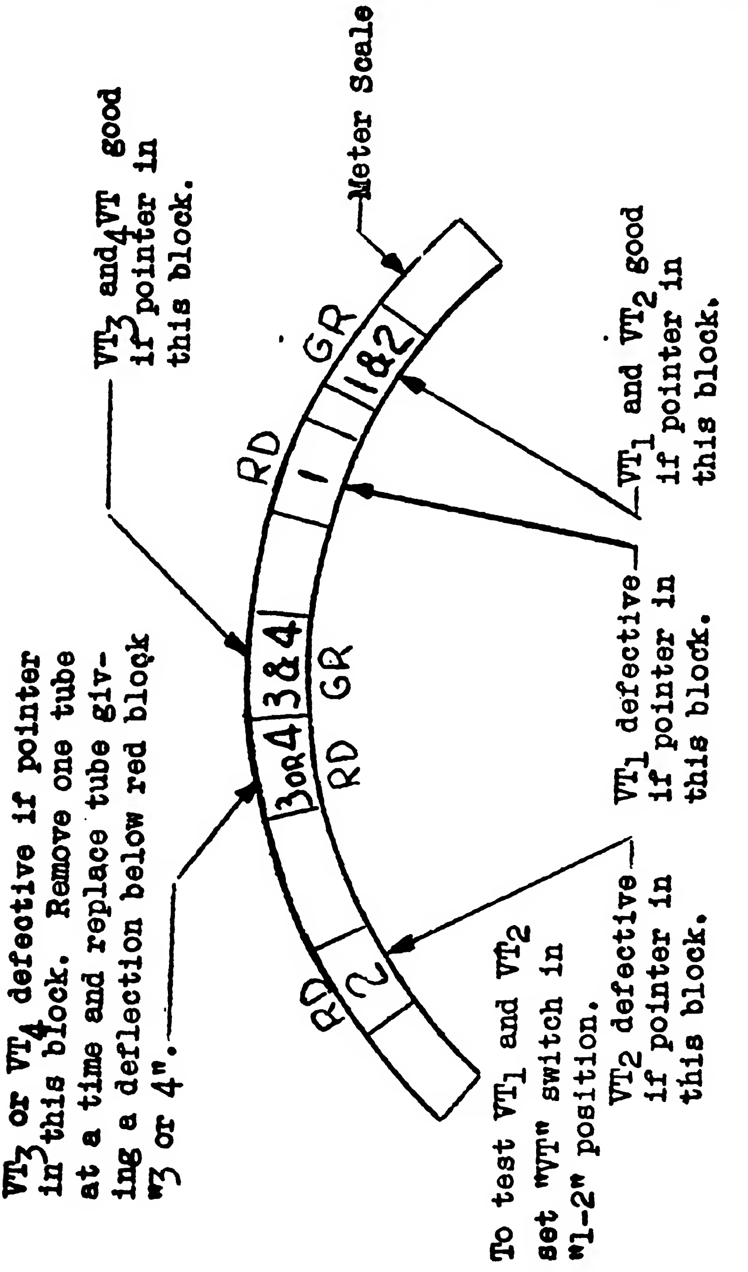
The grid leads of the 6J7 vacuum tubes, VT1 and VT2, should be wrapped around the tubes in such a manner that the grid caps do not point toward the 6L6 tubes, VT3 and VT4. Otherwise oscillation may be set up.

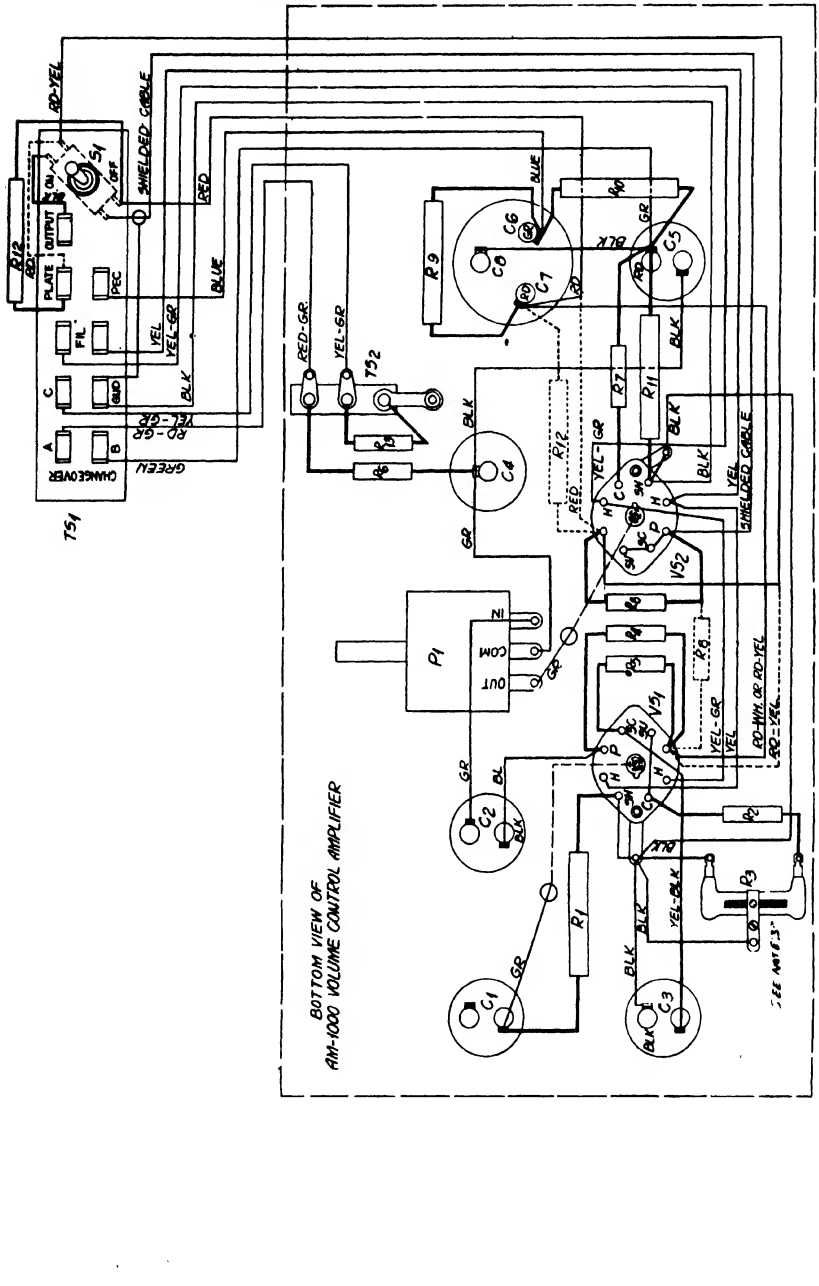
WARPING CIRCUIT

The warping circuit is connected for L2 H2 frequency response curve when shipped. If careful listening tests indicate necessity for a change, adjust in accordance with the instructions shipped with the system. In systems having more than one amplifier the warping circuit setting in each amplifier must be the same, since only one warping circuit is used at a time, and the amplifier selector switch supplied selects a warping circuit in an operative amplifier.

OPERATION OF AMPLIFIER

To place the amplifier in operation, set the "AC" switch in "ON" position. Be sure that the power transformer connection is in accordance with the instructions. Vacuum tubes should be tested each day as fol-

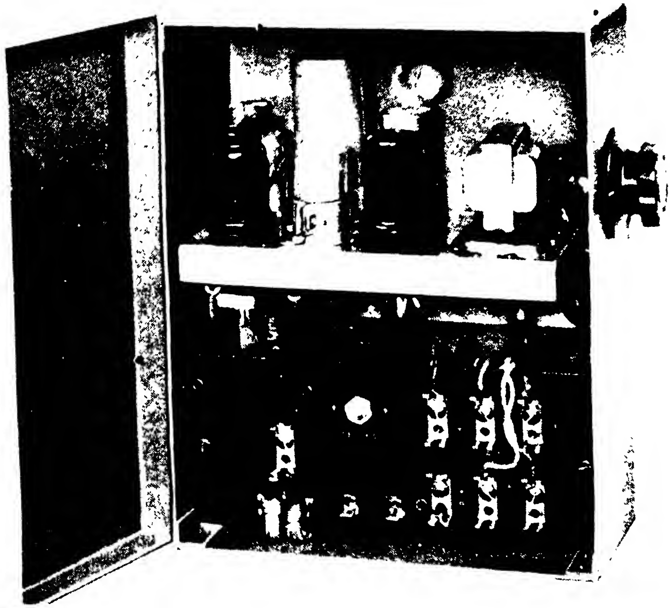

Meter Scale
VT3 and VT4 good if pointer in this block.
VT1 and VT2 good if pointer in this block.
VT1 defective if pointer in this block.
VT2 defective if pointer in this block.
To test VT1 and VT2 set "VT" switch in "1-2" position.
VT3 or VT4 defective if pointer in this block. Remove one tube at a time and replace tube giving a deflection below red block "3 or 4".
GR
1&2
RD
1
3&4
GR
3 OR 4
RD
2
RD


BOTTOM VIEW OF
AM-1000 VOLUME CONTROL AMPLIFIER
TS1
TS2
CHANGEOVER
PLATE
OUTPUT
PEC
FIL
GND
S1
ON
OFF
RD-YEL
SHIELDED CABLE
RED
BLUE
YEL
YEL-GR
BLK
RD-GR
GREEN
RED-GR
P1
IN
COM
OUT
V51
V52
R1
R2
R3
R7
R9
R10
R11
R12
C1
C2
C3
C4
C5
C6
C7
C8
RD-WH. OR RD-YEL
RD-YEL
YEL-BLK
SEE NOTE 3

lows, by means of the "VT" switch and plate meter, and all defective tubes replaced immediately. To test VT3 and VT4 set the "VT" switch in 3/4 position.

In border line cases remove one tube at a time. VT1 (with VT2 removed) is good if pointer is in red block "2."

VT2 (with VT1 removed) is good if pointer is in red block "1." If the pointer is below proper block in either test, install a new tube.



To avoid disturbances in the system, remove the tube with the grid cap attached. In case of a replacement, attach the grid cap before installing the tube.

Replace the rectifier tube if the pointer is below both green blocks "1 and 2" — "3 and 4" in the above tests, and repeat the tests.

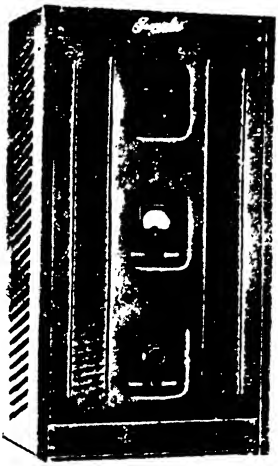
PLATE METER

Slight movement of the pointer of the plate current meter, may be observed before overload. It may

occur as much as 8 db before full load and is not an indication of distortion in the output stage, but merely of the variation in signal strength.

MAINTENANCE OF AMPLIFIERS

When two or more amplifiers normally operate in parallel, or emergency amplifier equipment is installed, a selector switch is supplied to disconnect the



output, external heater and plate circuits, and warping circuit of the inoperative amplifier, and connect similar circuits in an operative amplifier. Only one warping circuit is used at a time.

The input is not disconnected, and the AC power supply is controlled by the switch on the panel. Tests, parts replacements and frequency response measurements may therefore be made on the inoperative amplifier while the system is operating. Only when necessary should tests be made in the first stage, and then only after VT1 is removed, as disturbances will be introduced into the system. For frequency response measurements on the inoperative amplifier, connect terminal "RVC 3" to "RVC 4," and terminate the amplifier in 12 ohms if the selector switch does not provide this termination.

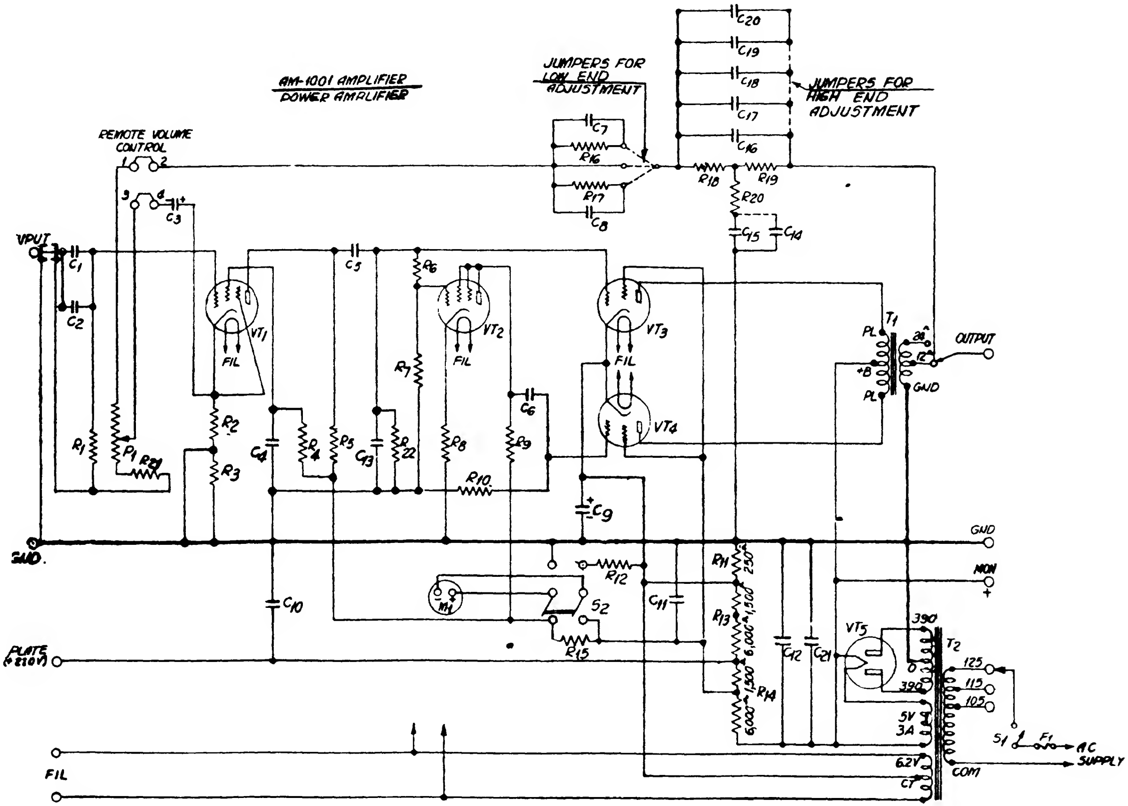
Test to see that tube prongs make good connection. Careful bending of the socket contacts may be resorted to if necessary. Tube prongs and socket contacts should be clean and bright. Burnish with crocus cloth if necessary. Check all clamping rings and nuts periodically, and tighten if necessary.

SIMPLEX AM-1003 AMPLIFIER

This is a chassis type, single stage, push-pull amplifier using one 6N7. The gain is 16 db., output 6 watts, input and output impedance each 50 ohms. External connections terminate in a 6-prong plug, which may be plugged into a standard 6-prong socket, thus facilitating installation. Heater and plate supply are obtained from the AM-1001 Amplifier.

The amplifier is used as a bridging amplifier across the input of the loudspeaker network to provide added power for the monitor loudspeaker. As a bridging amplifier draws practically no power, the full output of the amplifiers is available for the stage speakers. It may also be used to drive auxiliary speakers.

As a monitor amplifier, the AM-1003 should be plugged into the socket on the chassis of the loudspeaker network and the two screws furnished, threaded into the tapped holes in the chassis and tightened. Be sure that the external wires are connected to the "FIL" and "PLATE" terminals of the network. These three wires are the heater and plate supply for the amplifier.


AM-1001 AMPLIFIER
POWER AMPLIFIER
REMOTE VOLUME CONTROL
JUMPERS FOR LOW END ADJUSTMENT
JUMPERS FOR HIGH END ADJUSTMENT
INPUT
GND.
PLATE (+280V)
FIL
OUTPUT
GND
MON
AC SUPPLY
COM
VT1
VT2
VT3
VT4
VT5
T1
T2
S1
S2
F1
M1
390
125
115
105
5V 3A
6.2V
CT
250
1,500
6,000
PL
+B
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
C12
C13
C14
C15
C16
C17
C18
C19
C20
C21
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
R15
R16
R17
R18
R19
R20
R21
R22
P1

LOUDSPEAKERS

The principle of operation governing the speakers used in radio systems may be expressed as follows: "a variation in pull of a fixed magnet or electromagnet upon a diaphragm, iron bar (armature) or a coil of wire carrying a current.

The essential parts of a speaker which operates on the first mentioned principle is a constant magnetic field upon which is superimposed another magnetic field which varies in accordance with the electrical current equivalents of the sound wave, or expressed electrically, the audio frequency current. The combined action is motion of the diaphragm, armature or coil, in accordance with the audio frequency current.

The loudspeakers in use today are divided into three classifications. First, the moving armature, second the moving coil, and third the charged plates. Because of the utility in certain fields, it is also necessary to consider the moving diaphragm. As a point of interest it might be well to consider the methods employed to create the constant magnetic field. This is so because the method is not singular. The units which employ a permanent magnet, and these include the diaphragm and the moving armature, are known as magnetic units, whereas the units which employ a coil of wire wound upon a soft iron core and current flow through the wire are known as electromagnetic units. This classification includes the conventional dynamic "motor" regardless of the remainder of the speaker unit.

Perhaps we should start with the simplest form of loudspeaker and then progress onward until we reach the present day units. The word simplest is somewhat of a misnomer because it would lead one to believe that the unit is now obso-

lete. Such is not the case. We feel however that better comprehension of what is involved will be secured if we discuss the full list of popular systems. So much of the success of a sound system depends upon the successful application of the loudspeaker that everything is to be lost and nothing gained by just a bare knowledge of the device.

Consider for a moment, a structure such as that shown in Fig. 381 A, upper illustration, showing a permanent magnet with two upright pole pieces parallel with each other. The polarity of the two magnet ends are reproduced at the two ends of the upright pole pieces. Now imagine a side view of this arrangement with a bobbin of wire located upon each of these pole pieces as in the lower drawing. In sum and substance the pole pieces are the cores for the two bobbins or coils of wire.

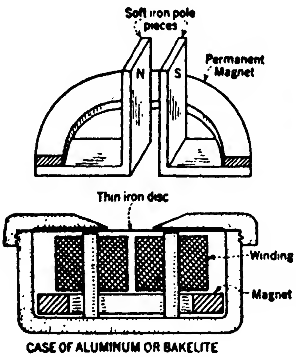


Fig 381A

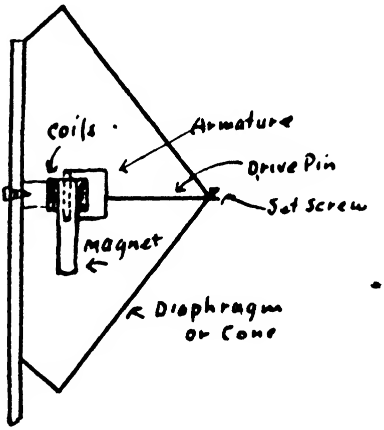
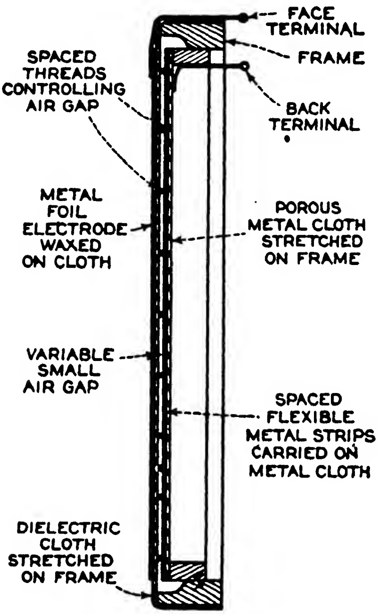


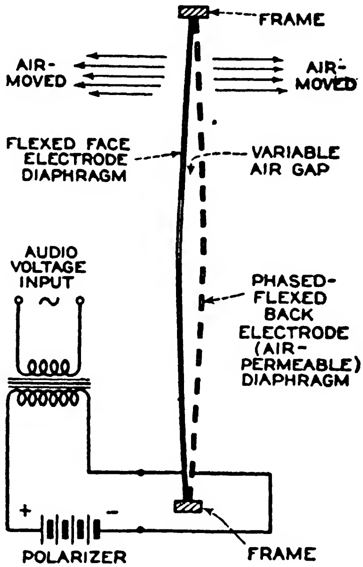
Fig 381B

Now imagine this structure arranged in a sort of housing, so designed, that it is possible to place a metallic diaphragm, possessed of magnetic properties parallel with the plane of the horseshoe magnet, atop the pole pieces and the bobbins but in such manner that there is a small clearance between the pole piece ends and the diaphragm. Atop this diaphragm is a cap with a small opening in the center. This is shown by the bev-

eled edges in the illustration. The diaphragm is designated as the thin iron disc. Several things take place in such a unit. First the diaphragm is attracted by the pole pieces attached to the permanent horseshoe magnet. The important point is that this attraction is independent of current flow through the



Section of acoustic condenser showing relation of parts.



Acoustic condenser action.

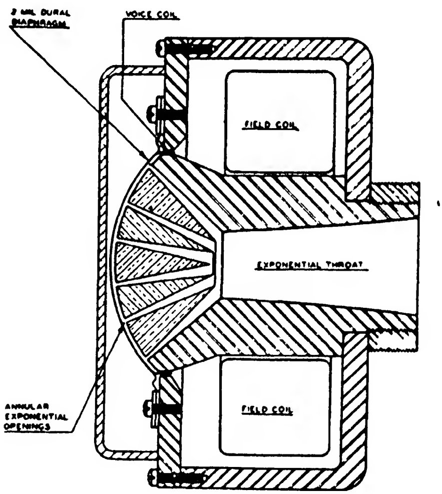
winding. This attraction exists whether or not current is flowing through the coils. Further this attraction is opposite to the spring action of the diaphragm.

If the current of an audio frequency is now passed through the coils, the field produced by the current is going to react upon the permanent field, due to the permanent magnet. The consequence will be a variation in the steady flux, and motion on the part of the diaphragm. Such movement will set air particles into motion, resulting in the radiation of sound waves

from the small opening.

The movement of the diaphragm, will be up and down when in the position shown. If desired a horn of conical shape may be attached to such a "motor" unit, with the orifice of the horn in position above the small cap opening of the speaker unit. Such a horn allows the progressive building up of the sound wave until at the bell, the greatest amount of air is set into motion, producing increased loudness and to a large extent, increasing the electrical efficiency of the complete unit.

However, the permanent magnet diaphragm type of unit, is very deficient. First it is resonant. That is, the diaphragm has its own period of vibration and if this frequency is within the band being transmitted, then amplitude of motion will be



Lansing 248E high frequency unit

excessive resulting in a hangover of that frequency, causing distortion. Second, the degree of magnetism possessed by the permanent magnet does not remain constant, and the unit affords a varying response over a period of time. Third the tension upon the diaphragm, causes it to lose some of its own spring tension, and after a period of time, the diaphragm is

bent, decreasing its responsivity. Fourth, the amount of current or the amount of power which may be applied to the unit is definitely limited and as it happens this amount is very small, very much less than that required for a sound installation. Fifth, the response characteristic of this type of loudspeaker motor is very poor, and when employed with a conical horn which by virtue of its shape, tends to discriminate against the

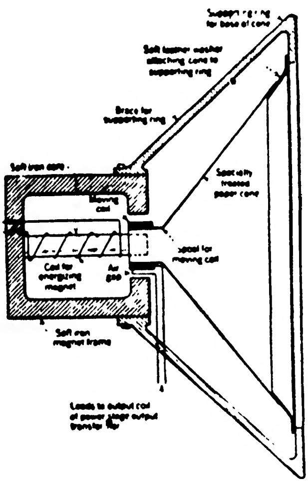


Fig 381C

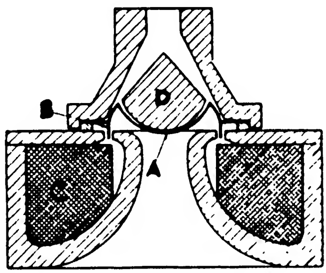


Fig 381D

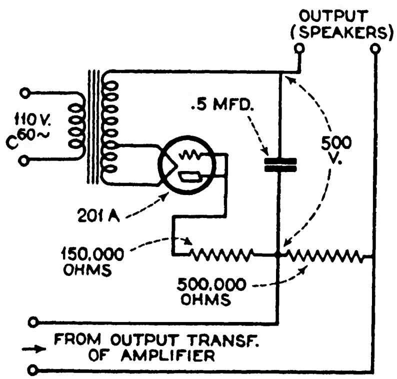
low notes produces a final response curve of very limited range, and definite preponderance of response between 1,000 and 3,500 cycles. Hence such units are not employed.

A unit of more popular design is shown in Fig 381 B. It is the conventional permanent magnet, moving armature system employed in many cone speakers. It is necessary at this time, to distinguish between the moving armature type of cone speaker, and the moving coil type of cone speaker. Referring once more to the moving armature, an armature is arranged as the core for a coil of wire located between the pole pieces of a permanent magnet. The armature ends are located between the pole pieces. The unit is so assembled, that the normal position of the armature, is midway between the pole pieces.

Audio frequency signal curves are then passed through the coil, and the reaction of the two forces is motion on the part of the armature, corresponding to the signal currents. This armature is linked by means of a level arrangement to the apex of a large conical diaphragm made of specially prepared paper, which resists changes in shape and stiffness due to variations in temperature or moisture. This part of the unit is the cone. The other part is the "motor."

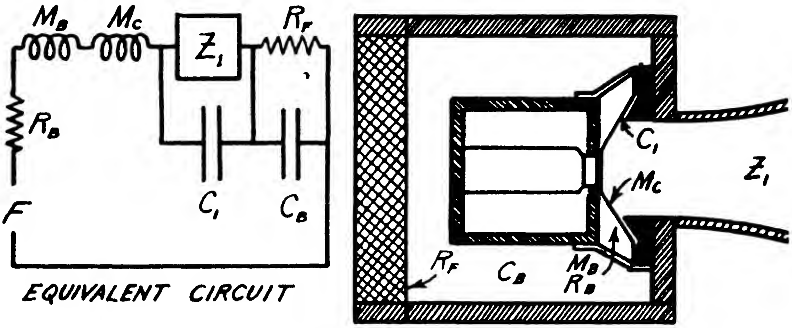
The diameter of the cone varies from 12 to 36 inches, an average of 18 inches being very popular. The outside edge of this cone is sometimes fastened to a support by means of a loose leather or chamois link, thus providing a support upon the outer periphery, yet minimizing reflection from a stiff supporting surface.

This form of unit possesses a much better frequency response characteristic than the diaphragm type of speaker, but even this is not the ideal because of certain inherent deficiencies. First is the vibration characteristic of the diaphragm. It does not vibrate as a whole, several modes of vibration being



present in the speaker, resulting in resonance of the diaphragm at certain frequencies. Further, the elements of the motor also possess definite resonance frequencies, particularly the linking medium between the armature and the cone. When viewed as in the illustration one would imagine that the motion of the

unit was that of a piston, yet such is not the case until a certain frequency is reached. At the low frequencies, the action of the lever is from "side to side." At high frequencies the piston action is approximated. Because of the character of the impulses applied to the vibrating surface, greater freedom from distortion is achieved at the high frequencies, whereas distortion is quite prevalent at the low frequencies.



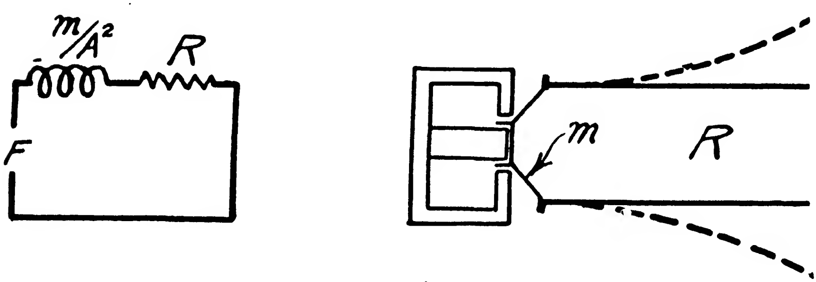
Complete equivalent circuit of dynamic cone.

The most popular type of unit is the dynamic or moving coil. This is available in two forms, as a cone and as a horn. Despite the radical difference in the appearance of the two speakers, the basic structure of the speaker "motor" is the same. An idea of the system is shown in Fig. 140C. It differs radically from the moving armature type of unit, as is evident in the illustration. Its principle of operation is the force exerted by a magnetic flux, set up in an airgap by current flow in a coil with a soft iron core, and another flux, set up by current flowing through a coil located in this same airgap. The two forces make the second coil move, hence the descriptive name of the speaker motor. Referring to the illustration, an electromagnet is so arranged, that an airgap exists between its pole pieces, and the complete magnet may be magnetized by a direct current set through a winding. This winding is known as the "field" and it is important to remember that current flow through it creates the magnetic flux across the airgap.

A conical diaphragm is so arranged that a small coil of per-

haps 10 to 150 turns of thin wire is attached to the apex of the cone. This winding known as the voice coil, fits over one end of the core of the field winding, and at the same time is within the airgap. Any motion on the part of the coil within the magnetic field, will be imparted to the conical diaphragms, since it is attached thereto and the diaphragm will then set a much larger column of air into motion.

In order to create a permanent flux across the airgap, so that the signal currents which are applied to the voice coil will create a flux which shall react upon the permanent flux and cause the coil to move, it is necessary that a supplementary source of power be employed with this type of unit. This is actually the case, a source of D.C. voltage and current being



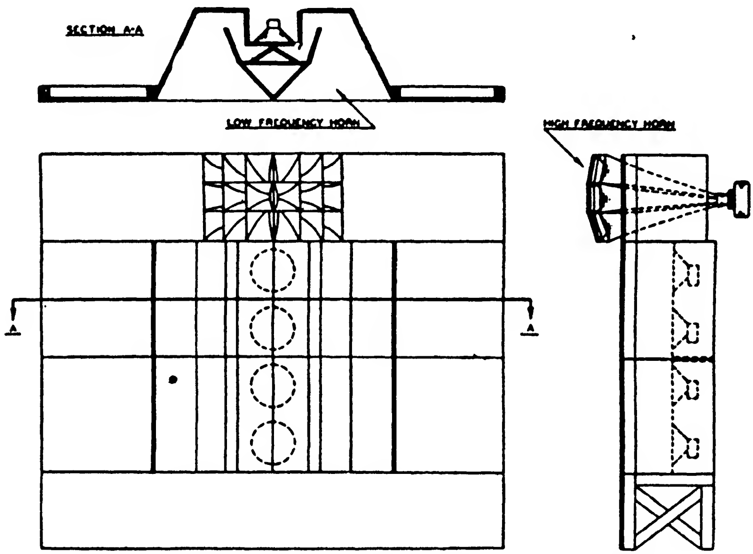
Equivalent electro-acoustical diagram of dynamic cone and acoustic impedance.

required to actuate the field coil or winding. More will be said about this later.

Exponential Type Speakers

The same form of motor structure is used in the exponential type of speaker. This type of sound reproducer differs from the aforementioned in several respects. Because of the difference in complete structure, it is necessary to employ a different type of motor, although the operating principle remains unchanged. The complete motor is encased in a housing. The field winding and the airgap remain unchanged. The voice

coil remains unchanged. The only difference is that a very small diaphragm, of stretched aluminum is used as the vibrating medium. The voice coil is attached to this diaphragm. The entire structure is housed within an iron container with a small opening on top, through which the vibrations of the diaphragm allow the passage of the sound waves created within the unit. An idea of the structure of the unit may be gleaned by reference to Fig 381D



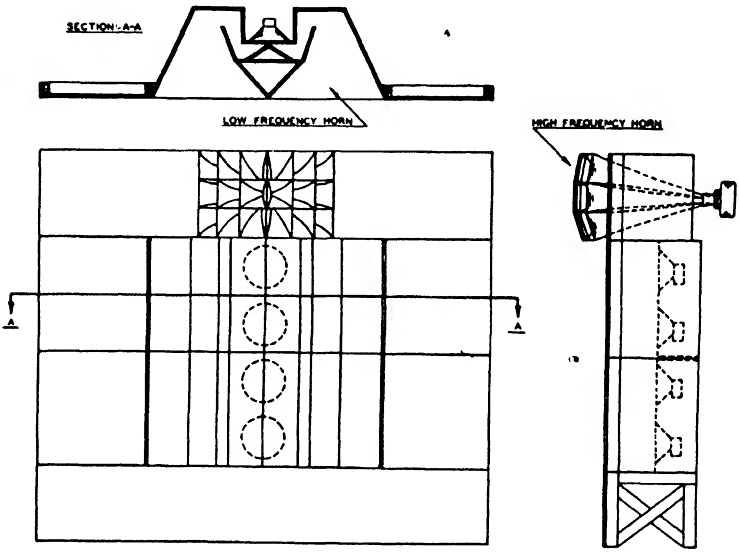
Shearer two-way horn system; folded type.

C is the field winding, B is the moving coil attached to the stretched aluminum diaphragm A. The location of the moving coil within the airgap is evident. As a point of information, the moving coil in the 555W is a single layer of aluminum ribbon wound edgewise. Other speakers employ a few or many turns of thin wire. One type of speaker employed in connection with a large cone diaphragm employs a single band of copper.

D is a plug used to shape the tone chamber, so that the proper distribution of air pressure is secured. This plug is used

in connection with the large horn which is operated in conjunction with this unit, and fits over the unit opening E.

Operating details are unnecessary since they are identical to the moving coil unit employed with a large cone. The horn however presents several interesting points. First it is known as the "exponential" a term applied to denote that the structure of the horn, primarily its expansion from the orifice to the



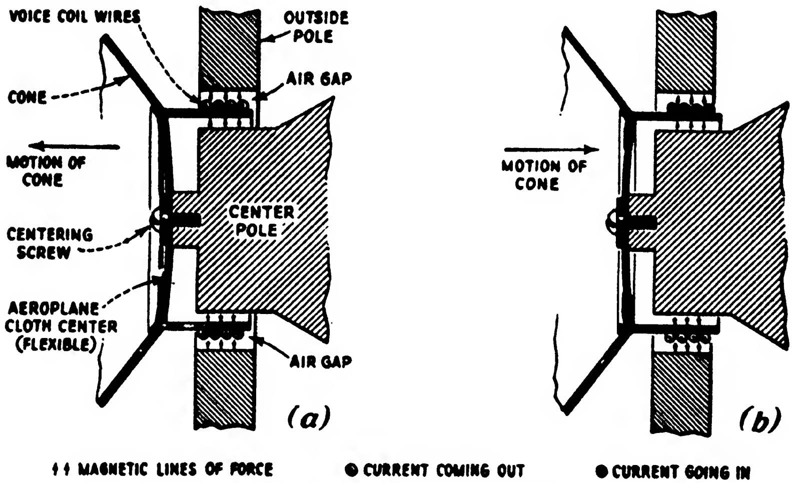
SHEARER TWO WAY HORN SYSTEM
FOLDED TYPE

bell is a mathematical expression. The rate of expansion of the cross sectional area of the horn of the exponential type, depends upon the lowest frequency to be transmitted because a certain opening (bell) is required in order to minimize reflection. This means that the lowest frequency to be transmitted governs the length of the air column within the horn, because starting with the opening of the orifice, it is necessary to build

up the horn in successive steps until the required opening is reached.

The diameter of the bell of the horn, if it is round must be equal in feet to one-quarter of the wave length corresponding to the lowest frequency to be transmitted by the horn. If the lowest frequency is 32 cycles, and since the speed of sound through air is 1,120 feet per second, the wave length in feet is

$$\frac{1120}{32} = 35 \text{ feet and } \frac{35}{4} = 8.75 \text{ feet must be the}$$



Operation of dynamic cone reproducer

diameter of the horn opening which will transmit 32 cycles. If the horn opening is to be square, it is possible to employ an area equivalent to the area of the round opening. The area of a circle is 3.1416 times the radius squared. This requirement of horn opening is due to the effort to minimize reflection. However one must realize that the opening of the horn mouth is not the sole important factor. The rate of expansion of the cross section area of the horn is also of equal importance and both factors must be considered in order that the desired re-

sult be secured.

The length of the horn being an important item, some method must be developed whereby exponential horns with from 8 to 16 feet air column length are practical for everyday use. This is accomplished by coiling the horn so that the complete horn occupies a space about 4.5 feet square.

To be successful, a speaker must deliver sound into every portion of the room or auditorium in a perfectly natural way, without the slightest inclination to being "tinny," "muffled," or "boomy." It is not only essential that the speaker have a complete frequency response range which must reproduce music with all its low frequencies, and with all its harmonics, and reproduce speech, so that it can be understood, but it must be reproduced so as to be heard completely throughout the theater.

An electrodynamic horn unit with an exponential horn is extremely directional, forcing all the sound directly in front of the speaker. The air in front of the speaker is moved practically as a solid mass, which fills the hall completely with sound. Both speech and music are distinct and individual instead of being jumbled.

We have seen that an exponential horn, is a horn which expands exponentially, or to put it more simply, it is a horn whose areas double at equal intervals along its length. These intervals determine the low cut-off of the horn. If the intervals are short, the cut-off is high; if the intervals are long, the cut-off is low. It is unnecessary here to go into the exact design showing the expansion required for a given cut-off, but we might mention that where a cut-off of 64 cycles is desired, it is customary to double the areas every 12 inches. Where a cut-off of 128 cycles is desired, the areas double every 6 inches, expansion rate, in order to prevent resonance of the bell, the bell opening must be of the proper size to conform to the cut-off for which the horn is designed. A horn with a cut-off of 64 cycles must have a bell opening approximating 2,100 square inches. If this bell opening is made considerably smaller, there will be a good deal of resonance at the bell, which will

muffle the low response.

Inasmuch as a horn is a carrier and projects sound which is a complete whole in itself, having all the harmonics and qualities of the individual instruments being reproduced through it, it is essential that it have no resonance of its own. For this reason, very many horns on the market are failures owing to the fact that the walls of the horn are extremely resonant. Paper, plaster, thin metal, thin wood, combinations of any of these, unless specially treated all make for extremely resonant horns. Of course, if these particular types of materials were made thick enough, resonance could be prevented, but this would result in horns which are commercially impractical on account of extreme weight and cost. Wood should be a minimum of 1″ thick, paper about 2″, plaster about 4″ and metal at least ⅜″. From this can be seen that horns manufactured from any one of these types of materials become entirely too bulky and too expensive to produce.

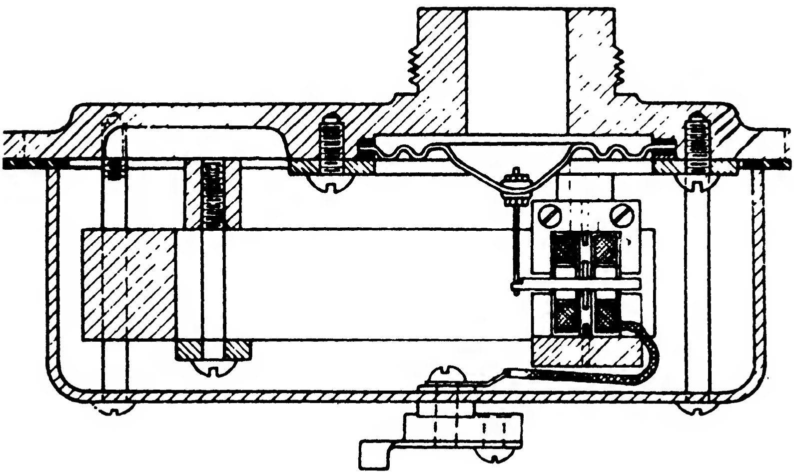
Dynamics with Baffles

The dynamic speaker motor employed in cone speakers must, because of a peculiar operating characteristic be assembled in a certain manner if good results are to be secured. Consider the illustration shown in Fig. 140C. If the diaphragm is set into motion regardless of its mode of vibration, air in the rear as well as in front of the vibrating surface will be set into motion. If these two waves mix, they interfere greatly with the response secured with the unit. Some provision must therefore be made to separate these two waves. Mixing results is a loss of sound volume and a particular loss of the lower audio register. To separate the two waves it is necessary to provide a long path of travel. This is accomplished by means of a baffle, a square block of sound absorbing material such as Celotex which is attached to the supporting frame of the speaker. An opening is provided equal in diameter to the maximum diameter of the vibrating diaphragm, thus affording a path for the propelled air.

The baffle has a very definite and precise technical function. In order that interference between the propelled waves be

minimized, it is necessary that the shortest mechanical path over which the sound waves can travel and intermingle shall be at least one-quarter wave length of the lowest note to be reproduced. This means that the area of the baffle for a 100 cycle note shall be 32 inches square, for a 30 cycle note, this path shall be (because of the shape of the baffle) 110 inches square. The thickness of the baffle depends upon its dimensions, and conventional types range from three-quarters of an inch to about one and one-half inches thick.

Quite naturally such speakers must be mounted on racks but every precaution must be exercised to preclude such location that free circulation of air to the rear of the speaker is pro-



Balanced armature type of loud speaker.

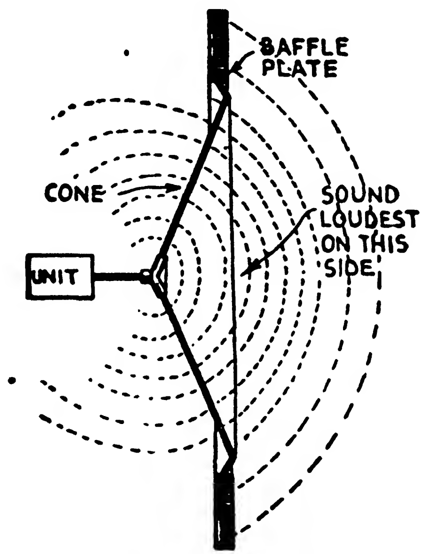
hibited. If such a condition is allowed to exist, cavity resonance will occur.

Technical Limitations

Let us now consider a few of the technical limitations of the speakers discussed thus far. Since the diaphragm type of unit is not in use and all indications point to its non-use in the

future, extensive discussion is not required.

Not so however with the moving armature or the moving coil type of unit. Referring to the former we note one very definite limitation. Since one end of the armature is centered between two pole pieces, the arc of motion is very definitely limited. Since the movement of the armature is a function of the current in the winding, which is the same as the power applied to the speaker, we find that the power input is very



Baffle Around Periphery of Cone

definitely limited. Excessive power will cause rattling because the armature will strike the pole pieces. This introduces another factor. In order that maximum power input be possible without contact between the armature and the pole pieces and since the armature moves in both directions it is imperative that the armature be correctly centered. Incorrect centering will greatly limit the movement of the armature before it strikes the pole piece, thus limiting the magnitude of power input. Furthermore, because of the motion of the armature, the degree of distortion present in the amplifier will influence

the movement of the armature. Incorrect plate current variation during the process of signal transfer through the amplifier will cause an excessive swing in one direction and excessive motion in one direction on the part of the armature. This becomes evident not only by distortion of the signal but by distinct audible contact between the pole piece and one side of the armature.

One need not be an engineer to comprehend that freedom of movement is an important requisite. This in turn, in very simple language means that all foreign particles must be absent from that small gap present between each side of the armature and the pole pieces. If such foreign matter is present freedom of motion is impaired and distortion accompanied by noise will be evident, because the full amplitude of motion representing magnitude of sound at some frequency, is not secured. The noise of course is due to the mechanical contact between the pole piece and the armature.

Now for a few technical considerations. The electrical efficiency factor of a loudspeaker is the electrical energy to sound conversion factor. The greater the amount of sound produced for a unit input, the greater the electrical efficiency of the speaker. Many elements enter into the powers which control the degree of efficiency. One can readily appreciate that the airgap between the armature and the pole pieces has much to do with the sensitivity of the device, the less the airgap the greater the degree of sensitivity. On the other hand the less the airgap, the less the permissible power input. Hence the first operation is a compromise between sensitivity and power. This item in turn is allied with another, namely the impedance characteristic of the speaker.

Another item of importance relative to the design of the speaker is the frequency response of the vibrating cone diaphragm and the sound power developed by the motion of the diaphragm. This item in turn is governed by the angle at the apex. An angle of 20° has been selected as the optimum for best tone quality and best sound power. Logically this too is governed by other factors, namely the type of material, used for the cone, its tension, etc. Since the tension is a matter of

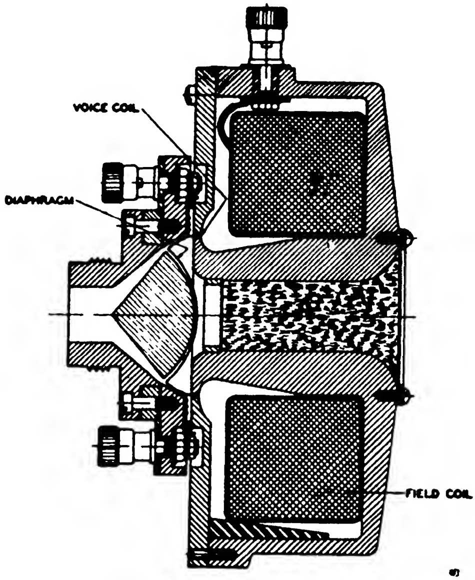
importance, any variation due to physical injury, atmospheric variation or such will impair the operation of the speaker. A tear or a crack will introduce sounds which were not in the original input and such diaphragms must be replaced. Loose diaphragms will be set into vibration by some tone and remain in that state for a longer period than the original, thus causing an overlap of sounds and consequent distortion.

With respect to the conversion factor (electrical energy into sound energy) the reader may be surprised to learn that the average moving armature type of speaker is distressingly inefficient, an efficiency factor of 2% being very high. The range is from .5 to about 2%, usually between .5 and 1.25%. Perhaps you wonder why? A few moments of thought applied to the elements involved will indicate the reasons. First, is the loss in the electrical circuit. Second is the loss in the magnetic circuits, hysterises and eddy currents. Third, is the loss in the linking systems. These elements which are normally straight pieces of metal are actually bent during the operation of the speaker and a large amount of power is dissipated to overcome this inertia and resiliency. Fourth is the tension of the diaphragm. The significance of this statement is best appreciated by the man who has had the occasion to observe the motion of a vibrating surface under the stroboscope.

Speaking of the electrical circuit, we find the moving armature type of unit very deficient in one respect, a matter now alleviated by the introduction of the moving coil unit. However, with respect to the moving armature system, the complete electrical assembly presents a reactive impedance to whatever device (the output tube in the amplifier) supplies the power.

Since the speaker is located in that part of the amplifier circuit where power amplification takes place, it is necessary that a certain optimum tube plate to load impedance ratio obtain. Further the power transferred to the load from the source depends upon this ratio. Since the load impedance is reactive it naturally varies with frequency and since the electrical energy in the circuit is the equivalent of a sound input, it stands to reason that its frequency is anything but constant. Hence we must operate with a variable load impedance. This condition

influences results in two ways. First is the effect of the frequency variation upon the lower audio register. The speaker



Sectional diagram showing the diaphragm, air chamber, and throat construction of the *555* type receiver.

winding has a definite minimum impedance, the D.C. resistance of the coil. This is so because the normal inductance of the device is seldom greater than 3 henrys and the reactance of this value of inductance at 30 or 40 cycles is very small. Hence at low frequencies, the total impedance of the speaker is low, many times, much less than the output plate impedance of the tubes that feed the speaker. The result is distortion. Supplementary to this is a decided loss in power because of the very poor impedance ratio. As a matter of fact some speakers do not function on frequencies as low as 100 cycles. This statement it should be understood pertains to the moving armature type of reproducer. As the frequency is increased, the speaker impedance increases. At one frequency the optimum impedance ratio is passed, moving up, and the degree of power trans-

fer again decreases, until at some high frequency, say 5,000 cycles, the impedance of the speaker may be as high as 45,000 ohms, which when compared with a tube impedance of 2,000 cycles is not very conducive to good power transfer. Thus we find a loss of power on the high as well as the low notes.

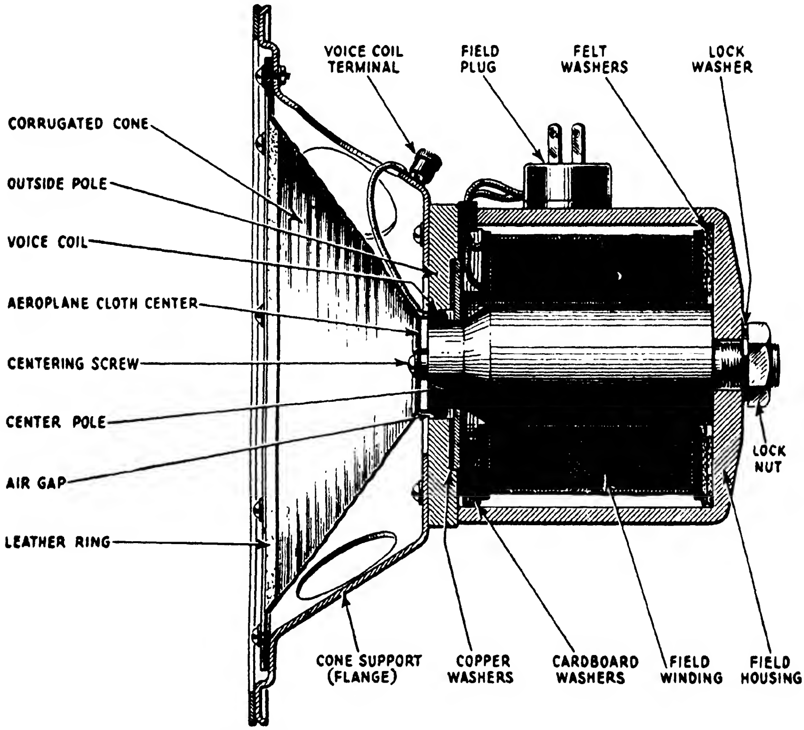
With respect to distortion, the greatest amount is encountered upon the low frequencies, with minimum on the high frequencies. Once again a study of the vibrating surface by means of this stroboscope is of extreme advantage. This variation of power transfer influences what is known as the frequency response characteristic of the loud speaker. The ideal unit would be one which responded with equal facility to all frequencies. Such is not available in the moving armature type of unit regardless of the structure of the vibrating surface. In addition to the above controlling force, one must needs consider the possibility of resonance in the diaphragm and the other metal moving parts. Such resonant conditions are encountered at which time accentuation of certain frequencies takes place with injury to the reproduction. Thus the moving armature type of speaker presents numerous difficulties.

The moving coil system eliminates many of these troubles. One cannot however say that this type of speaker regardless of the use of an exponential horn or a baffle is free of distortion, but one can say that many of the possible reasons for distortion present in the moving armature unit are absent in the moving coil arrangement.

With respect to mechanical losses, this unit too, is far from being perfect. We must still contend with the tension of the diaphragm and with the energy expended to bend the cone, but the degree of conversion of electrical energy into sound energy is much greater. Such units are about 15 to 20% efficient, which while it does not appear great when considered numerically is however a tremendous improvement over the moving armature unit.

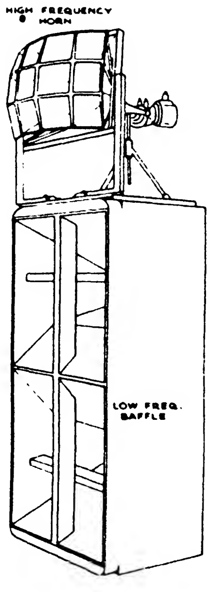
With respect to the frequency characteristic, the dynamic unit is far superior to the moving armature. We distinguish in this fashion because both speakers bear the "cone" designations and confusion is apt to occur with the word "cone" applied to

both. In contrast to the variable reactive impedance of the winding in the moving armature speaker, the impedance of the moving coil remains practically constant over the entire audio frequency spectrum. This is accomplished by the use of a few turns of wire of such nature that the entire impedance is practically all resistance. These speakers possess an impedance varying from about 1 ohm to 15 ohms. Not that the variation of impedance in any one speaker is of such value but that the various speakers upon the market at the present time are of some impedance value within that range. No matter what the impedance, it remains practically constant between 30 and 6,000 cycles.



Of course the frequency response is not ideal, but design has reached the stage where by means of corrective filters, it is possible to secure very satisfactory response with the ideal in

mind. The possibility of resonance is still present, both in the material comprising the cone and the complete vibrating structure. With respect to the latter, every effort is made to adjust the resonant frequency to some value below the normal audio band. With respect to the paper and the coil resonant frequencies are to be found in the neighborhood of from 1,000 and 1,500 cycles. The series resonant circuit is employed to alleviate the resonant condition by reducing the current entering the moving or voice coil at this frequency. Other resonant

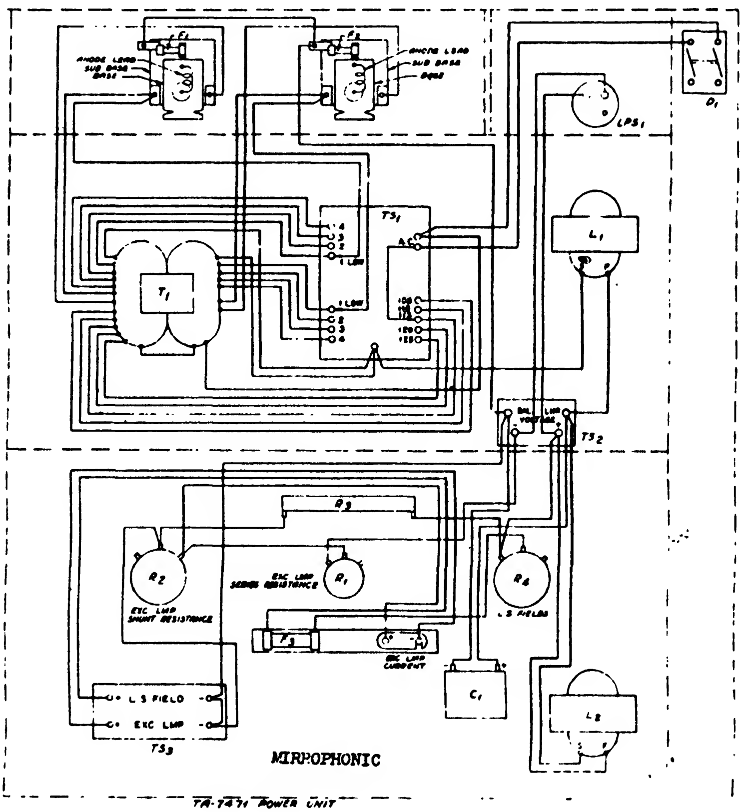


frequencies are also present at high values, but they do not complicate matters.

What was said about the cone with respect to the moving armature type of speaker is applicable to the moving coil unit as well. We made reference in an earlier paragraph that speakers should not be housed in such fashion to allow cavity resonance. When a speaker is located in a cabinet or in a corner of a room in such fashion that free circulation of air is not available, some frequency transmitted into the speaker

coil and made audible by the vibrating surface will start sympathetic vibrations in the air confined in the cabinet. This air may vibrate for a longer period than the duration of the original impulse, thus producing a "hangover," and creating the "boomy" effect. This sound is due to the fact that such resonant frequencies occur in the neighborhood of about 200 cycles. In some cases the frequency is higher because the cabinet walls or the speaker mounting is not sufficiently rigid and capable of vibration when the proper tone (frequency) is sounded. Such conditions must be avoided because they introduce interfering frequencies.

SE-7522 LOUDSPEAKER SYSTEM



SPEAKER SYSTEMS

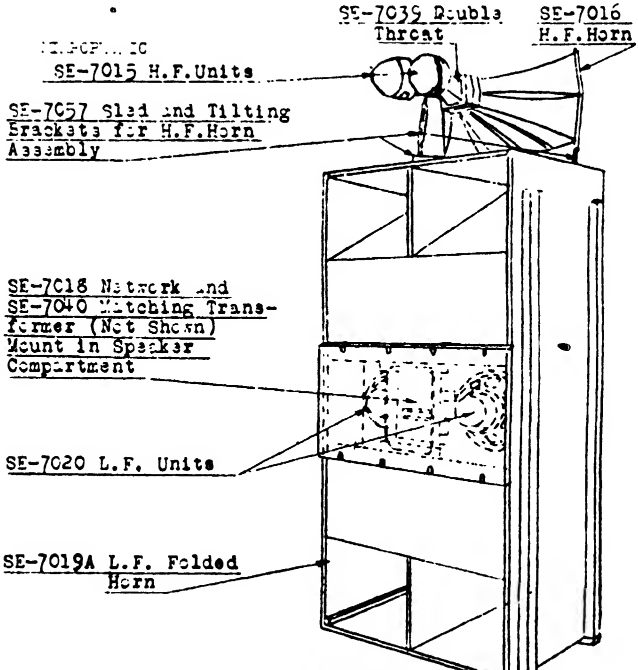
MIRROPHONIC LOUDSPEAKER SYSTEM

The SE-7511 Loudspeaker System is of the "two-way" type comprising separate electrical and acoustical channels for efficient reproduction of high and low frequency sounds in motion picture sound systems. It includes an electrical filter, or "dividing network," to split the electrical energy from the sound system amplifiers into its high and low frequency components, a large folded exponential type horn driven by two electro-dynamic cone loudspeaker units to convert the low frequency electrical energy into low frequency sounds, and a specially constructed electro-dynamic metal diaphragm-type loudspeaker unit, cast metal throat, and large multi-cellular metal horn to similarly convert high frequency electrical energy into the higher frequency sounds and distribute them over the auditorium seating area. A triangular angle-iron supporting sled for the high frequency horn assembly is also included to facilitate phasing operations and to provide means for adjusting the tilt of the assembly. The complete loudspeaker system is intended to rest on the stage floor directly in back of the perforated sound motion picture screen, although in larger theatres where the stage must be cleared, the loudspeaker system may be attached to the screen frame, be supported from stage lines or a trolley system, or may be mounted on a suitable dolly so that it may be rolled into a stage wing when necessary.

INSTALLATION

The SE-7019-A Folded L. F. Horn is designed to allow for mounting with the longer dimension either horizontal or vertical. The efficiency (ratio of total acoustical output energy to electrical input energy) is

slightly greater with the longer dimension horizontal and with the horn resting solidly on the stage floor. The angular distribution of energy is wider and more even, however, about the long axis of the horn, and this consideration therefore, in an auditorium of the usual proportions, would call for having the longer dimension vertical. This position has the added advantage of providing a suitable support for the HF speaker assembly at about the correct height for best screen illusion in such auditoriums.



ASSEMBLY
SE-7522 LOUDSPEAKER SYSTEM

For high houses with one or more balconies, better results will usually be secured by having the longer dimension horizontal. Experience indicates that in such cases, best F. H. horn coverage is secured by having the H. F. speaker system fairly well down on the screen, in fact, resting on the L. F. horn. In this po-

sition it is close enough to main floor front seats to provide plenty of direct sound energy even though the H. F. horn assembly is tilted upward a considerable amount to give direct sound energy to upper balcony seats.

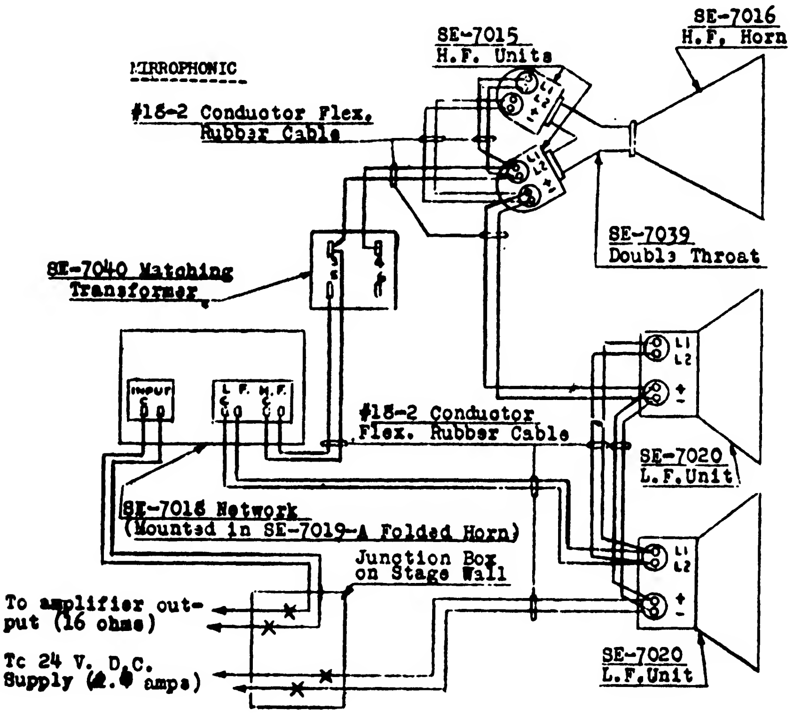
From the foregoing it should be evident that choice of mounting position depends to some extent upon auditorium geometry. The choice should also take into account any known acoustical defects, such as excessive reverberation and reflections from hard boundary surfaces. For example, in a house with a flat, untreated ceiling but with some absorbing material on the side walls, the vertical position would probably be best because it reduces the amount of L. F. sound energy reaching the major reflecting surface. For untreated and hence highly reflective side walls, the horizontal position might give noticeably better results.

Remove the wing nuts and washers securing the rear cover of the L. F. horn speaker compartment and take off the cover. Mount the two L. F. speaker units taking care that cones are not damaged by accidental contact with mounting bolts; this operation is most easily and safely performed with the L. F. horn resting face downward on the floor, provided space permits. Mount the network to the support blocks in the speaker compartment with the wood screws and washers provided. Assemble the H. F. horn, throat and unit, and rig the assembly on the support sled. The sled members go together with the tapping projections upward so the bottom surface of the sled will be smooth and hence free to slide on the L. F. horn surface supporting it for phasing operations. The sketch shows the assembled relationship of the various components for the vertical L. F. horn position.

Make connections to the network and the loudspeaker units in accordance with the sketch, or, where the loudspeaker system is part of a standard sound system, in accordance with the sound system conduit and connections diagrams. If there is doubt as to final

L. F. horn position, leave sufficient slack in connection cords to allow it to be turned about.

The face of the H. F. horn needs to be as close as possible to the rear screen surface in order to prevent troublesome H. F. sound energy reflections from the rear surface of the screen. For trial, and prior to actual phasing tests, both horn faces may be placed as close as possible to the screen surface. Screen masking

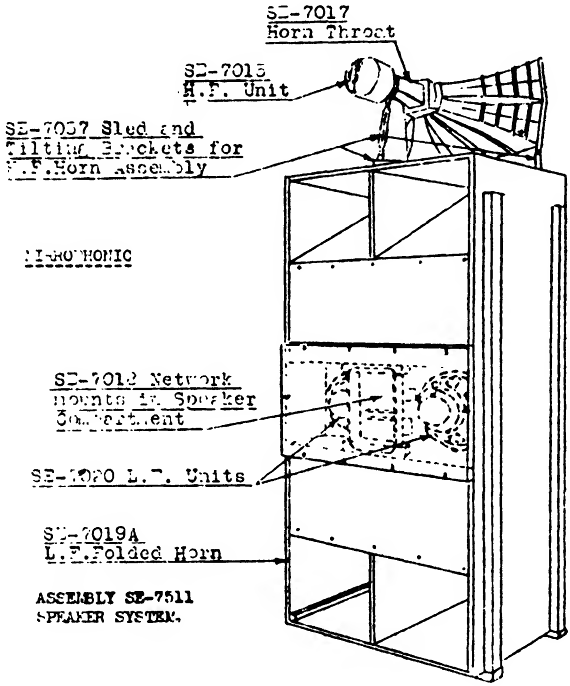


partially covering the mouth opening of the L. F. horn is not very harmful unless the masking material is exceptionally thick and heavy, in which case it should be replaced with black scrim cloth or other light weight material.

OPERATION AND ADJUSTMENT

The acoustical energy output of the H. F. channel

is purposely made higher than and adjustable with respect to that from the L. F. channel in order to permit good balancing under all screen and auditorium acoustical conditions. It is varied by connecting the two blue strap wires inside the network chassis to similarly numbered terminals of the two tapped attenu-



ASSEMBLY SE-7511
SPEAKER SYSTEM

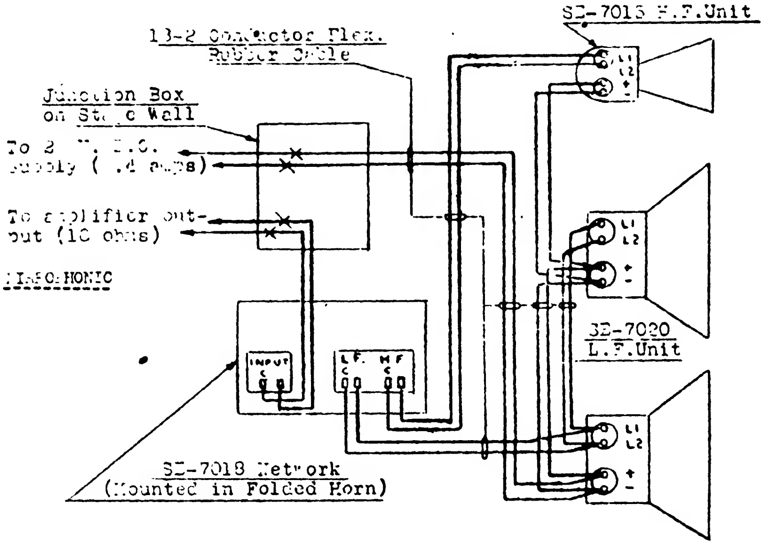
ator resistors. The numbers indicate the amount of attenuation in db. For an auditorium of average acoustical properties, and assuming that the sound picture screen is in good condition for the transmission of sound through its perforations, the attenuation will need to be in the order of 2 db. If the sound screen is not in good condition, or if large amounts of material having considerable H. F. absorption are present in the auditorium, less attenuation will be required for good balance. More attenuation might be required in situation where small audiences, little H. F. absorbing

material, or the use of worn and noisy films cause reproduction to be harsh or objectionably noisy. It is usually better, however, to compensate for such conditions by suitably equalizing the amplifier response, since the network attenuator affects all frequencies down to 40 cycles, the crossover frequency.

For best quality sound, the longitudinal position of the H. F. speaker assembly with respect to the L. F. speaker must be adjusted so that the acoustical energy output of the H. F. and L. F. channels will be "in phase," that is, will add, and not cancel in the crossover frequency region. This operation should be performed before final amplifier equalization is undertaken since it affects the apparent sound quality. There are numerous phasing methods in use. One which gives consistent results is as follows. The H. F. horn assembly is first properly tilted to give even distribution of sound energy throughout the auditorium as evidenced by listening tests. A reel containing fairly heavy male dialogue is then run. An observer in the auditorium is asked to note when the largest difference in sound quality is noted as the voice coil leads to the H. F. speaker units are reversed for various longitudinal positions of the H. F. speaker assembly with respect to the L. F. baffle. Once the point of maximum difference in sound quality is determined, even an untrained observer will be able to tell which voice coil connections gives best quality. With correct phasing screen characters appear to be speaking from the screen rather than from some point behind it, and H. F. sounds are clean and clear, while L. F. sounds are full without being boomy. Phasing will be found less critical when the L. F. horn is vertical due to its resulting smoother response in the crossover frequency region. If the phasing point comes where the face of the H. F. horn assembly is more than a few inches from the screen, another equally good point can be found by changing the relative horn positions approximately 16 inches (1/2 wavelength of sound at 400 cycles) to bring the H. F. horn mouth ahead of the face of the L. F. horn, at the same time reversing the H. F. unit voice coil leads. The

L. F. horn face need not be close to the screen surface, but as has been previously pointed out, the H. F. horn mouth should be, for reduction of sound reflections from the rear screen surface.

When the phasing operation is complete, firmly fasten the H. F. horn sled to the L. F. horn, and suitably mark the leads to the H. F. unit terminals so they may be correctly reconnected after removal for tests or servicing.



Unless the stage volume is very small, or is fairly well filled with drapes, scenery, etc., better auditorium sound quality will usually be secured by an approximate acoustic isolation between stage and auditorium except for the horn mouths. The isolating material may consist of heavy drapes, wall board, old scenery, etc., arranged to close off the back of the screen (except for horn mouths) as well as possible, and to extend to the sides of the proscenium arch. If there is considerable stage apron space in front of the screen, it may be necessary to cover it with carpet or other sound absorbing material to reduce sound reflections.

The direct sound energy may be increased by positioning the H. F. speaker so as to project as much energy as possible toward the seating area, and by making certain that the sound screen is in good condition for transmission of sound through its pores. The amount of reflected sound energy may be reduced by positioning the speakers so as to keep as much sound as possible from reaching large reflecting surfaces, by isolating the stage volume from the auditorium as noted, and by the general application of acoustical treatment in the auditorium.

Some of the exceptionally good L. F. performance of the loudspeaker system is due to the use of the large type L. F. horn, the most efficient type of L. F. reproducing system currently available. This extended range of L. F. response is obviously all to the good in auditoriums of good acoustical qualities, for under such conditions, the wider the range of sound frequencies reproduced, the more natural and life-like become speech and music quality. Unfortunately, one of the most common auditorium acoustical defects, excessive reverberation (the prolongation of an individual sound by multiple reflections from the auditorium boundary surfaces), is most troublesome at the lower audio frequencies. The right way to treat such cases, of course, is to correct the bad acoustical conditions by the installation of suitable corrective materials in the auditorium, but it must be recognized that there are cases where, for economic or other reasons, this cannot be done.

Some means for combating the adverse effects produced by excessive reverberation have already been outlined, and these should certainly be tried before resorting to the following measures which all reduce the overall frequency response range of the sound system. Where speech intelligibility is seriously impaired by reverberation, an improvement can always be obtained by reducing the L. F. acoustical energy output of the sound system. This can be done electrically in the amplifiers of most motion picture sound systems, and this is undoubtedly the easiest way to do

it. Another, and sometimes more effective scheme, consists of supporting the entire loudspeaker system on a scaffold structure at about one-half to two-thirds picture height above the stage floor. The L. F. horn, as well as the H. F. horn, may be tilted to direct its sound energy at the seating area which fills up first so as to take maximum advantage of the large audience absorption factor.

It should be reemphasized that these procedures partly defeat the object in providing good quality loudspeaker equipment, and they should be regarded as expedients to be used only until poor auditorium acoustical conditions can be corrected. Well-upholstered chairs, heavy aisle carpets, and cloth drapes are among the most effective kinds of acoustical treatments, and the various companies producing standard acoustical

products such as plasters, fibre tiles, and soft wall boards will be found very willing to offer advice upon the corrections of auditorium acoustical defects.

SERVICING LOUDSPEAKERS

The loudspeaker system requires an occasional cleaning and an inspection of connections for tightness.. The wing nuts and washers securing the rear cover of the L. F. horn speaker and network compartment should be kept tight to prevent rattles, and it is advisable to at least once per year check and tighten all screws, nuts, and bolts in the entire loudspeaker equipment for the same reason.

The voltage at the loudspeaker unit field terminals should be periodically checked with a voltmeter and adjusted as closely as possible to 24 volts. Variations as large as 25% (18-30 volts) have little effect on performance, however, since the windings have large safety factors with respect to both magnetization and heat dissipation.

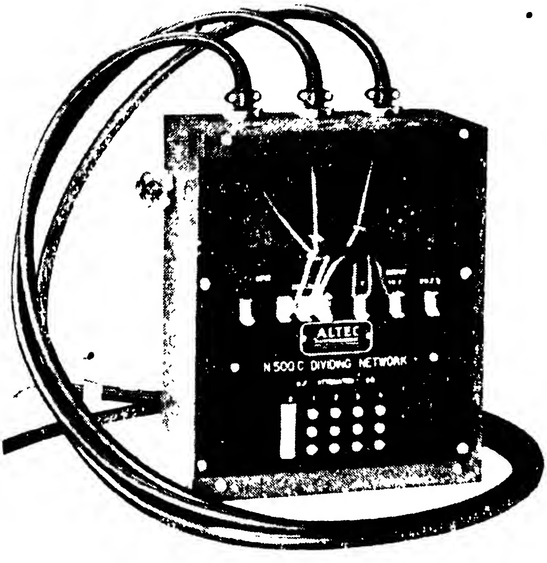
VOICE OF THE THEATER LOUDSPEAKER

The first newly developed theater loudspeaker equipment to be offered in many years, and certainly a major development in sound reproduction, has recently been announced by the Altec Lansing Corporation. There are ten different models of this loudspeaker line—all but the very smallest utilizing the same high and low frequency units, high frequency multicelluar horns, and the same type of low frequency horns, so the quality of the equipment furnished for smaller and medium-sized theaters is identical to that furnished for the very largest.

Perhaps the most important feature of the new high frequency speaker of the "Voice of the Theater" is a design which fully utilizes all of the advantages of the new war-perfected Alnico 5 type permanent magnet. The exclusive design of the new speaker in combination with this new type permanent magnet permits higher efficiencies at one-third the size and weight of material required for all other type magnets. It also

provides a compact self-energized speaker which needs no separate field supply.

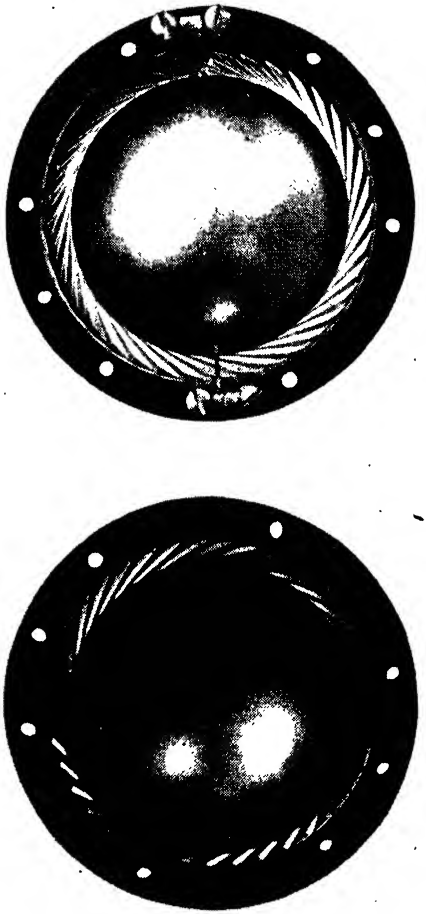
Equally important is the feature of using edgewise wound, aluminum ribbon wire in winding the voice coil. This new type aluminum ribbon wire, treated with a temperature resistant varnish, greatly increases the efficiency by providing more conductor material in the magnetic circuit.



N-500-C dividing network.

Another feature is the almost perfect piston action of the metal diaphragm resulting from the use of tangential rather than the usual annular edge corrugations. Metal diaphragms are well known to be more sensitive and more even in response than those made of paper or other fibrous materials. The complete voice coil and diaphragm assembly is mounted in a cast bakelite ring. Dowel pins assure perfect alignment. Impedance of the speaker is approximately 24 ohms

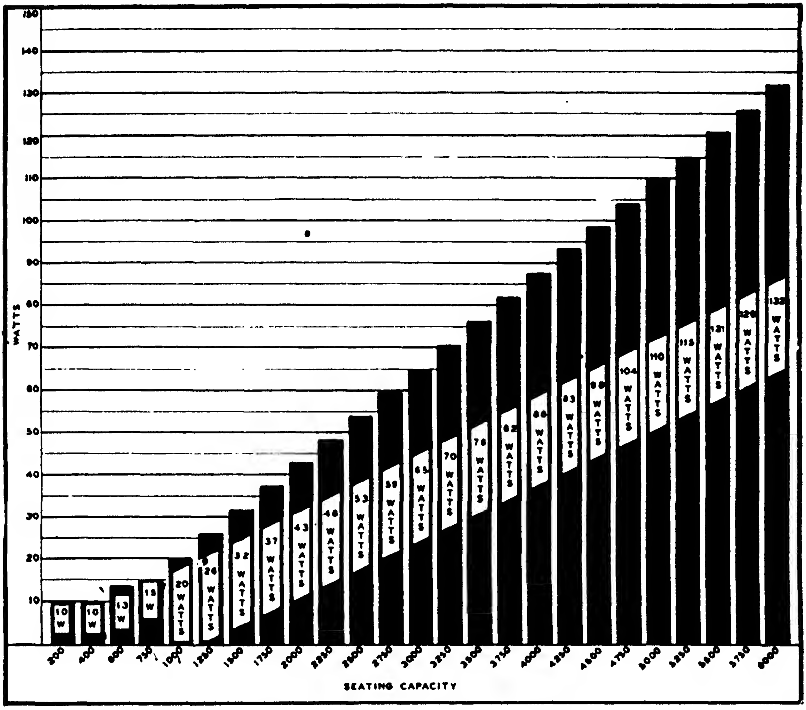
over a wide frequency range when operating under normal conditions. Parallel type, constant resistance dividing networks are provided with each system. Crossover point is at 500 cycles. Provision is made for



Front and rear views of 288 replaceable diaphragm assembly.

four steps (1 db each) of attenuation in the high frequency output. This is accomplished by changing the

shorting strip held down by three screws. Input impedance of the unit is 12 ohms. In model A-6 the cross-over point is at 2,000 cycles.



ACADEMY RESEARCH COUNCIL MINIMUM POWER REQUIREMENTS FOR THEATRES
MINIMUM RECOMMENDED AMPLIFIER OUTPUT BASED UPON SEATING CAPACITY OF THE AUDITORIUM
THEATRE-SOUND STANDARDIZATION COMMITTEE
RESEARCH COUNCIL — ACADEMY OF MOTION PICTURE ARTS AND SCIENCES

The seamless moisture resistant cone has an effective driving area of 123 square inches and is mounted in a heavy die cast frame to insure perfect alignment of the voice coil in the air gap of the magnetic structure. The air gap is completely enclosed by the cone spider and center dome to keep out dust and dirt particles.

Being self-energized, the unit requires no separate

field supply and this also results in hum-free performance and decreased operating temperatures. The voice coil impedance is approximately 20 ohms under normal operating conditions. For proper safety factor, installed amplifier power should not be in excess of the following:—

A1-X	200 Watts
A1	100 Watts
A2-X	150 Watts
A2	80 Watts
A4-X	60 Watts
A4	40 Watts
A5	30 Watts
A6	20 Watts

The dividing network used is a parallel-type constant resistance network. It consists essentially of a low and high-pass filter designed to operate from a common source at their inputs. The insertion loss is less than one-half db. The attenuation slope is approximately 12 db per octave on either side of the crossover frequency.

Sufficient damping of the vibrating elements of the units are provided in the magnetic circuit so that it is not necessary to provide additional damping from the driving amplifiers.

SIMPLEX LOUDSPEAKER SYSTEM

Two-way speaker systems with multicellular high-frequency horns and folded low-frequency horns are employed in all Simplex Sound systems. The small system employs one "A" type high-frequency units and one "B" type low-frequency unit. The medium system employs two "A" type and two "B" type, while the larger system employs two "C" type and four "D" units. The "C" and "D" units differ from the "A" and "B" mainly in power-carrying capacity.

PHASING OF STAGE LOUDSPEAKERS

The schematic of connections in the standard "C" system is shown in the sketch Plate S-40.

High and low frequency speakers should be in phase electrically, and each should be tested as shown in Plate S-41, using a voltmeter and battery. Do not break the loudspeaker field to test polarity as the speaker may be damaged.

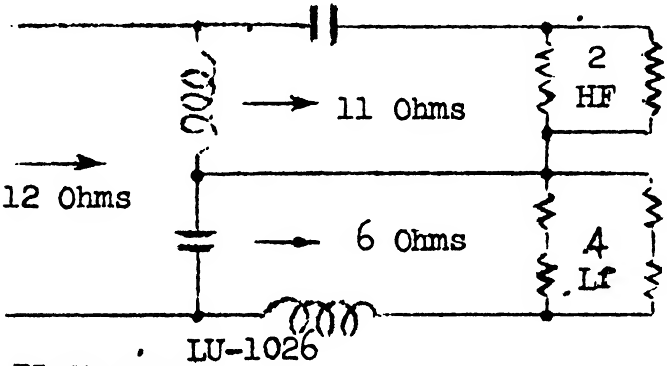


PLATE S-40

POSITIONING OF HORNS

The horns should be positioned initially as shown in diagram. After the horns have been finally set for distribution a standard test reel should be run, and the high frequency horn and cradle moved back and forth until best quality is obtained. Then nail the cradle securely to the LU-1015 Horn.

HIGH AND LOW FREQUENCY LOUDSPEAKER UNITS

The LU-1010 Low Frequency Loudspeaker Unit is an energized moving coil, cone type speaker, 15" in diameter, and weighing 27 lbs. The voice coil impedance is 6 ohms, maximum power handling capacity 25 electrical watts, field coil resistance 1600 ohms. Field excitation of 200 volts DC, 30-40 watts power consumption per unit, is obtained from the PU-1003 Power

Unit. Two of these units mount in an LU-1015 Low Frequency Horn. The LU-1015 is a wooden, folded exponential horn.

The LU-1011 High Frequency Loudspeaker Unit is an energized, metal diaphragm moving coil speaker, $6\frac{1}{2}$" in diameter, and weighing 24 lbs. The voice coil

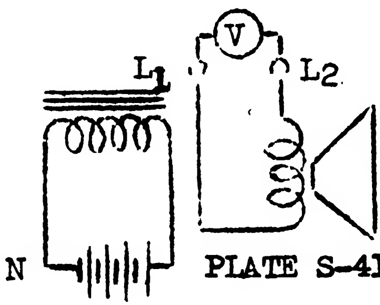


PLATE S-41

impedance is 22 ohms, maximum power handling capacity 25 watts with a 400 cycle crossover network. The field coil resistance is 2500 ohms. Field excitation of 220 volts DC, 20-25 watts power consumption per unit, is obtained from the PU-1003 Power Unit. Two units mount on the LU-1012 (3x4), LU-1013 (3x5), LU-1014 (3x6) or LU-1019 (2x5) High Frequency Horn. The high frequency horns are multicellular, exponential horns made of lead coated metal.

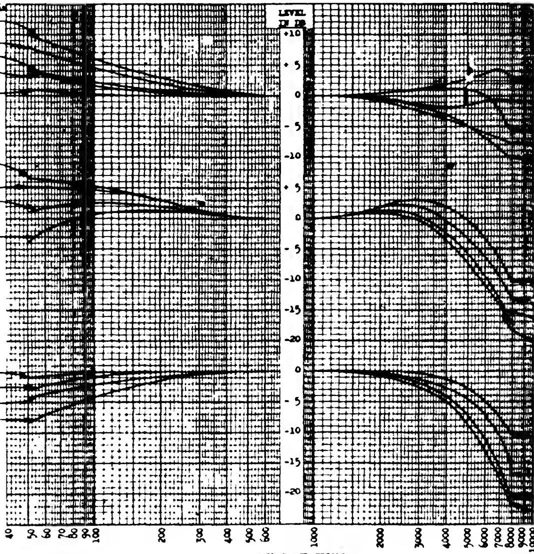
ADJUSTMENT OF WARPING CIRCUIT IN AM-1001 AMPLIFIER

The warping circuit in each AM-1001 Amplifier is set for the L2 H2 curve (See Plate S-42). If, after carefully positioning the horns, listening tests indicate the necessity for a change in the frequency response characteristic, the warping circuit may be adjusted per Plate S-42. Only one warping circuit is used at a time. When all four amplifiers, or only the two amplifiers in the upper cabinet are operating, the warping circuit in the lower amplifier (No. 1) is used. When only the two amplifiers in the lower cabinet are operating, the warping circuit of the upper amplifier (No. 2) is

PLATE S-42

LOW END ADJUSTMENTS

Connect (See Fig. 1)	Disconnect	Desig.
C_1 & C_2 in parallel. A to 1	R_{17}	a
C_7 & C_U in series across R_{16}		
C_1 & C_2 in parallel. A to 1	—	L-1
C_1 & C_2 in parallel. A to 2	—	L-2
C_1 & C_2 in parallel. A to 2	C_7 & R_{17}	b
C_8 & R_{16} in parallel.		
C_1. A to 2	C_2	c
C_1 & C_2 in parallel. A to 2	C_8 & R_{16}	d
C_7 & R_{17} in parallel.		
C_1. A to 1	C_2	e
C_1 & C_2 in parallel. A to 2	—	f
C_7 & C_8 in series across.		
R_{16} & R_{17} in parallel.		
C_1 & C_2 in series. A to 2		g
C_7 & C_8 in series across.		
R_{16} & R_{17} in parallel.		
C_1 & C_2 in parallel. A to 3	—	L-3
C_1 & C_2 in series. A to 2	—	h
C_1. A to 3	C_2	L-4
C_1 & C_2 in series. A to 3	—	L-5

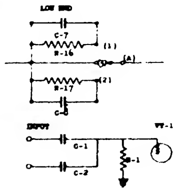


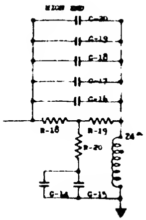
HIGH END ADJUSTMENTS

Desig.	Connect (See Fig. 2)	Disconnect
i	C_{14}, C_{15}	$C_{16, 17, 18, 19, 20}$
j	C_{15}	C_{14} & $C_{16,17,18,19,20}$
H-1	C_{14}, C_{15} & C_{16}	$C_{17, 18, 19, 20}$
k	C_{16}	$C_{14, 15}$ & $C_{17,18,19,20}$
l	-	$C_{14, 15}$ & $C_{16,17,18,19,20}$
m	C_{14}, C_{15} & C_{16}, C_{17}	$C_{18, 19, 20}$
n	C_{14}, C_{15} & C_{16}, C_{17}, C_{18}	C_{19}, C_{20}
o	$C_{14,15}$ & $C_{16,17,18,19}$	C_{20}
p	$C_{14,15}$ & $C_{16,17,18,19,20}$	
H-2	C_{15} & C_{16}, C_{17}	C_{14} & $C_{18, 19, 20}$
H-3	C_{15} & $C_{16, 17, 18}$	C_{14} & $C_{19, 20}$
q	C_{15} & $C_{16, 17, 18, 19}$	C_{14} & C_{20}
H-4	C_{15} & $C_{16,17,18,19,20}$	C_{14}

LOW END CURVE DATA
CYCLES & DEVIATIONS FROM REFERENCE IN DB.

Curve Desig.	50	55	100	130	200	300	600
a	+10	+9.5	+6	+4.8	+3	+1.5	0
L-1	+ 8	+7.4	+4.5	+3.5	+2	+1.0	0
L-2	+ 4	+3.8	+2.2	+1.7	+0.9	+0.4	0
b	+ 4	+1.5	+1.5	+1.0	+0.5	+0.2	0
c	+ 1.2	+1.0	[illegible].2	0	0	0	0
d	+ 6.6	+6.5	+5.2	+4.6	+3.0	+1.5	0
e	+ 5.1	+5.1	+4.7	+4.2	+3.0	+1.5	0
f	+ 1.6	+1.5	+2.5	+2.5	+2	+1.2	0
g	-4.0	-2.8	+0.6	+1.0	+1.2	+1.0	0
L-3	-1.0	-0.8	-0.2	0	0	0	0
h	-3.0	-2.5	-0.8	-0.5	0	0	0
L-4	-4.2	-4.0	-2.2	-1.7	-0.8	-0.4	0
L-5	-8.2	-7.7	-4.2	-3.0	-1.5	-[illegible].5	0





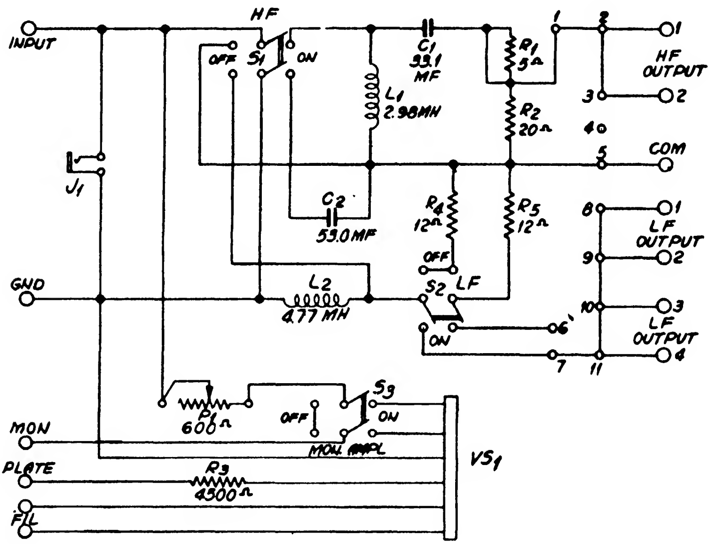
HIGH END CURVE DATA
CYCLES & DEVIATIONS FROM REFERENCE IN DB.

Curve Desig.	1000	1500	2000	3000	5000	7000	8000
i	0	+0.2	+0.5	+1.2	+2.8	+ 4.2	+ 2.8
j	0	-0.2	-0.4	-1.4	-1.5	- 0.6	- 1.0
H-1	0	+0.2	+0.5	+1.0	+1.0	- 2.5	- 6.5
k	0	-0.2	-1.0	-2.5	-5.0	- 7.0	- 7.8
l	0	-0.2	-0.5	-1.7	-5.0	- 8.8	-10.4
m	0	+0.6	+1.9	+3.0	-0.4	- 6.6	-10.4
n	0	+0.6	+1.8	+2.0	-3.4	- 9.7	-13.4
o	0	+0.5	+1.2	+0.5	-5.8	-13.[illegible]	-17.5
p	0	+0.5	+0.8	-0.2	-7.5	-14.5	-17.5
H-2	0	0	0	-0.2	-2.8	- 7.5	-10.5
H-3	0	0	-0.2	-1.2	-4.6	-10.8	-17.0
q	0	0	-0.5	-2.0	-7.2	-15.8	-21.0
H-4	0	-0.2	-0.9	-2.7	-8.8	-17.5	-22.2

used. The warping circuit setting should be the same in all amplifiers.

ACOUSTICS OF AUDITORIUMS

The shape of the auditorium, the material used on the walls and ceiling, the decorative drapes on the walls and the type of seats and carpeting used determine the acoustic properties of the auditorium, and the final positioning of the stage horns. When reverberation and reflections are encountered, special considerations apply.

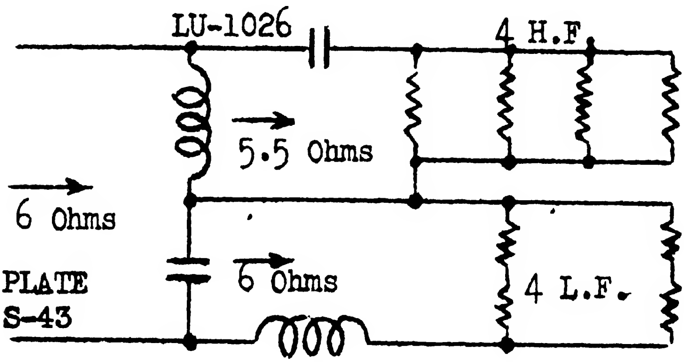


SIMPLEX LU-1026 NETWORK

REVERBERATION

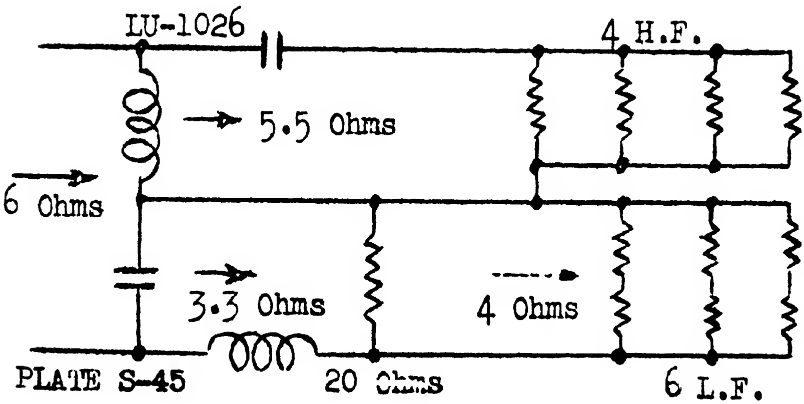
When the contours of the walls and ceiling are such that there is no concentration of sound but reflections from many sources, due to the non-absorption qualities of the surfaces, the multiple reflections result in a general mass of sound known as reverberation. It may be recognized by the persistence of sound after the source has stopped.

In such auditorums the stage horns should be set so that direct sound is projected into the seating area, and does not strike any reflective surfaces.



REFLECTION

In auditoriums, having large reflective surfaces, such as flat or curved walls, ceiling domes, etc., reflected sound may be concentrated in certain areas within the seating section of the auditorium. Such a



condition, depending upon the source of the reflected sound, is known as side wall, back wall or ceiling "slap," and results in distorted sound in those areas.

SIDE WALL "SLAP"

To eliminate side wall "slap," the two upper outside cells of the high frequency horn may be plugged with wool yarn. Do not pack tight. The yarn should be in a loosely formed cone.

CEILING "SLAP"

Tilting the high frequency horn downward so that the direct sound is projected into the seating area and does not strike the ceiling will generally eliminate ceiling "slap."

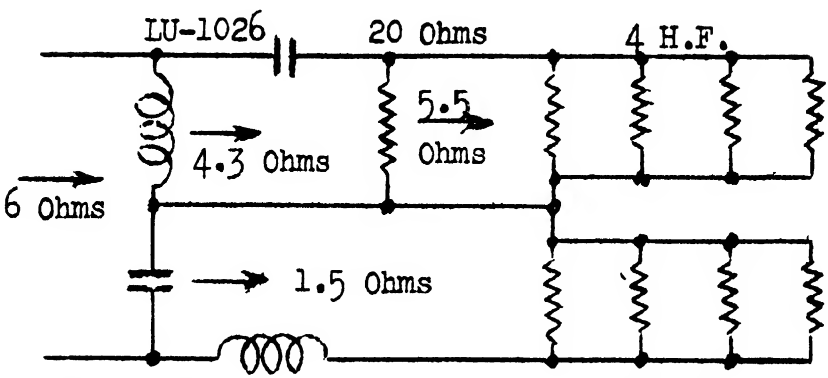


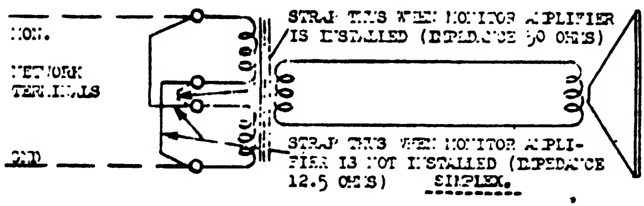
PLATE S-44

BACK WALL "SLAP"

This condition is probably the most difficult to clear, especially in houses with high balconies or large unbroken back wall areas as the direct sound may be reflected from the back wall to the seating area, or to the ceiling and then into the seating area. Under these conditions the following adjustments are suggested:—

If possible, the high frequency horn should be tilted downward so that direct sound is just heard in the last row of seats, in which case the audience and seats will usually absorb the sound and avoid reflections.

If the condition still exists, the entire loudspeaker system should be moved off center on the stage, and adjusted to give proper distribution. This change al-



ters the reflection pattern, and back wall "slap" may not be noticeable.

Another method of altering the reflection pattern is to angle the loudspeaker system with respect to the screen. The amount of rotation necessary for effective results depends upon the size and shape of the auditorium and the nature of the surfaces.

SPECIAL STAGE LOUDSPEAKER COMBINATIONS

In order to obtain high quality reproduction, as well as adequate distribution in certain auditoriums of unusual configuration, special stage loudspeaker combinations may be supplied. Three such combinations are shown in schematic form, Plates S-43, S-44, S-45. The LU-1026 Network, LU-1010 L. F. Unit and LU-1011 H. F. Unit are used in each case.

With four H. F. Units in parallel, and four L. F. Units in series parallel, a flat characteristic with 400 cycle crossover is obtained as the H. F. and L. F. circuits are of about equal impedance. The L-Pad in the network should be disconnected. Plate S-43.

With four H. F. Units in parallel, and four L. F. Units in parallel and the 20 ohm section of the network L-Pad resistor connected, crossover is at 375 cycles with a dip in the response characteristic at this point. Plate S-44.

SOUND-PICTURE PROJECTION

Since in the final analysis the quality of sound reproduction is largely dependent upon the technique which the projectionist brings to bear upon his functions, his role in the new scheme of things has become an increasingly important one. The public, educated through past experience, has come to appreciate this fact, and its patronage is extended accordingly. The question, "Does the house have good sound reproduction?" assumes only slightly less importance than the star of the picture, or the picture itself, and its reaction to the question, therefore, has a definite economic significance for the projectionist. His value, and indeed his very survival in the business, is predicted upon this ability to turn out consistently smooth reproduction, unmarred by breakdowns or irregularities in the recording. The latter phase requires some sense of artistic appreciation; the former, a comprehensive knowledge of the technical requirements of his equipment, and careful attention to its proper upkeep.

As in other fields, the development of an adequate technique begins with the very ordinary details of routine operation. These must first be reduced to a strict science for in these details the artistry of presentation will have its roots. A procedure is here outlined which may serve as a useful guide to projectionists in the standardization of their daily routine; an orderly method of checking the sound equipment is outlined; and certain troubles which may possibly occur during operation are listed, together with their remedies. Some hints whereby the projectionist may enhance his value through skillful covering up of the deficiencies of the recordings are also given. The installation treated is assumed to be one having both film and disc reproduction.

STARTING AND TESTING

The projection machines should be thoroughly cleaned of film dust, oil, etc. Special care should be taken to keep the sound gate always clean and smooth, and to prevent dirt from piling up on the rollers in the soundhead. Even a small particle of hardened film on the gate or rollers will cause an unevenness in the progression of the film, which may introduce a chatter into the sound reproduction. After cleaning the machines, thoroughly clean and polish the illuminating lamp and the lens system; the former with a soft, clean cloth, the latter never with anything else but lens tissue, which is especially made for this purpose and will not scratch the lenses or leave lint on them. Examine and clean all openings in aperture plate and tension pad. Dirt or dust on any of these components may result in insufficient illumination with subsequent loss of volume.

LAMP FOCUS

After cleaning has been finished, illuminating lamps of both projector's should be checked to see that they are focussed properly. Vibration of the machine is apt to knock the lamp slightly out of adjustment in the course of a day's run. Also with age, the lamp filament has a tendency to sag, which, of course, changes its line-up with relation to the slit in the lens system; this must be carefully guarded against. Another effect of aging is to blacken the walls of the lamps, resulting in insufficient light getting to the photoelectric cell, even though the lamp is run at its proper rating. For this reason, whenever a lamp becomes noticeably discolored, it should be replaced by a new one.

Any of the conditions mentioned will result in a decrease in volume of the sound, and quality also may be affected.

To adjust the lamp properly, its holding screw is loosened, and the lamp is then turned until its filament is straight with relation to the axis of the lens tube. Keeping this adjustment, the lamp is moved up or down until the filament image is centered exactly on the slit in the lens tube, as observed through the window usually provided for this pur-

pose. Where this arrangement does not obtain, a small piece of white paper may be inserted ahead of the photoelectric cell, so as to center the light upon it. When the filament image is properly centered on the slit in the lens tube, the brightest light will be obtained on this miniature screen. It will be necessary to remove the light gate to the photoelectric cell for this purpose; the paper, or card, is held up against the opening which goes to the photoelectric cell. The light should be observed for shadows at the edges, and if these are observed, the lamp should be moved sidewise, or vertically, as the case may be, until they disappear. In no case should the lamp focus, which is pre-set by the manufacturer, be disturbed. When lining-up has been completed, clean the lamps thoroughly once more to remove dirt or oil from fingers, which may have been deposited on their walls during handling.

AMPLIFER CHECK

The amplifiers are next thrown on and permitted to warm up for a few seconds; in this procedure it should be made standard practice to always throw on the filament switch first before the plate switch is thrown. In shutting down, the reverse procedure should be followed, i. e., plate circuit disconnected first, then the filament circuit. This prevents sudden large surges of electron emission with subsequent damage to tubes.

Meters should be carefully checked to determine whether circuits are normal; particular care should be taken with the plate current reading, as this is in thousandths of an ampere, and even slight deviations from normal are relatively important.

It is an excellent practice to keep a daily log, and thus have an accurate check-up on these readings. After making this check, the system is set up for normal reproduction.

Several test records of good quality—both film and disc—should be kept on hand for the purpose of establishing the daily criterion of performance. The film records need only be a couple of hundred feet long, while the discs can be somewhat longer, if desired, since their cost is about the same regardless of length of recording. The most desirable

records for this purpose will be simple vocal solos with violin or piano obligato. For convenience, duplicates should be available so that the projectionist can cut back and forth between his two machines so as to ascertain relative balance in volume, and check possible differences in quality, of the respective outputs.

The volume control or fader—if this serves the dual purpose—is always set at the same point each day for this test, and the volume is regulated so that the sound can just be comfortably heard at the rear of the empty house. The projectionist should make this check himself while his assistant runs the machines, or where this is not practicable, he should have a competent observer, perhaps the house manager or owner, assist him.

It is important that the same individual makes the test each day; otherwise it is not of much value. The reason for setting the volume at the lowest possible level, is that any dropping off from this level will be much more apparent to the ear, than if a larger ratio of sound obtained; the output of the monitoring horn in the booth may serve as an additional check during this test.

Some installations are not provided with adequate checking facilities. If the equipment does not include meters for checking the individual plate currents of the tubes—especially the rectifier tubes—the projectionist will do well to have a reliable radio serviceman come in once a week to take these readings. A log should be kept of the readings, and when any tube falls off from normal reading it should be replaced. This precaution may prevent a number of breakdowns during the performance, and the expense of such service is negligible.

The headphones mentioned for testing circuits are sometimes supplied by the manufacturer of the sound equipment. If they are not, an ordinary pair of radio telephones of 2000 ohms resistance or better will suffice. Solder a 6 inch length of hard drawn copper wire of about No. 8 gauge to each cord terminal; these make a convenient pair of picks for getting across amplifier terminals which may not be easily accessible otherwise. The ends of the picks may be filed down to points, and the picks covered with a length of cambric "spaghetti" for insulation.

A spare photoelectric cell which has been tested in circuit should be kept on hand; it is also desirable to have available a spare disc reproducing unit for quick replacement in case of trouble. Several spare exciter lamps should also be on hand. These may be pre-set during the projectionist's off time by correctly positioning them for the best light, then marking a scratch on their bases which coincides with a reference mark scratched on the lamp collar holder in the projection machine. In case of a burn-out during operation, one of these lamps can be quickly installed without going through the process of lining up and adjusting for correct position.

It should not be necessary to mention the safeguard of having spare fuses available in each fuse box. Fuses have a habit of blowing just when there are not spares available, resulting in unnecessary delay in getting back into operation. The habit of coppering the fuse socket is exceedingly bad practice, and may result in serious damage to the equipment.

A convenient test lamp for the purpose of quickly checking fuses is made of an old socket to which are attached two short lengths of fairly stiff insulated wire; a 25- or 50-watt lamp is the only additional equipment required. Bridging across the fused line—ahead of and behind the fuses—will indicate at once the presence of an open fuse by failure of the lamp to light. Other equipment which the projectionist should have in the booth are an electric soldering iron, several pairs of wiremen's pliers, and several size screwdrivers; these inexpensive tools may prove invaluable to the equipment.

REFINEMENTS OF OPERATION

As mentioned previously, the projectionist's duties do not end with the proper maintenance of equipment; he is responsible also to a large degree for the artistic rendition of the sound accompaniment. Theoretically, this is entirely taken care of in the recording, but unfortunately, under present production methods, the theory does not always square with practice.

In a good many cases abrupt differences in sound level are encountered when changing reels; again, when the closeup of an individual player is shown, quite often the sound level is not increased proportionately, with the result that the closeup illusion is destroyed. Sometimes when some loud, terrifying noise is intended to accompany the action, the relatively small difference in recording levels allowed enfeebles the effect; one hears loud, raucous conversation, commands, shouts, then a supposedly huge explosion goes off with only a slightly louder "pop." The result is ludicrous. Equally bad are such effects as footsteps approaching along a gravel path which sound like a herd of pachyderms trampling down a forest of young bamboo, in comparison to the dialogue level.

CUE SHEETS AND MONITORING

Admittedly these are faults of recording which should have been corrected at the source, but with the producers in a rush to catch up with belated release schedules, such irregularities in the sound accompaniment are often condoned. It is up to the projectionist then to smooth these out as much as possible before passing them along to the audience. Careful rehearsal of each new picture is necessary to ascertain where gain manipulation will help the sound, and cue sheets showing these changes in fader settings should be prepared. In order to function intelligently in these manipulations, however, the projectionist must be provided with an adequate monitoring horn in the booth.

It is the writer's experience that in a large percentage of sound installations, the entire purpose of the monitoring horn is nullified, by having it run at too low a level. The primary purpose of this piece of equipment is to act as the criterion of quality and volume of the sound in the house; usually it serves only to indicate that the amplifier in the booth is operative, and to no other purpose. If the monitor is run so low that the noise from the projectors override it, then obviously it will be difficult to detect differences in volume—even fairly large differences—which may occur during the performance.

It may be argued that the rehearsals suggested should

afford the projectionist an adequate basis for his manipulations, but when such changes must be made on a cue word, it is difficult, if not impossible, to time them accurately when working blind in this manner. The monitor level should be adjusted so that it can be comfortably heard above the noise of the projectors; it should not, of course, be so loud that it will be heard outside of the booth.

The horn should be of the same type used in the house and should have reasonable fidelity of tone. Too much stress cannot be laid upon this matter of suitable monitoring facilities; without them the projectionist is almost entirely isolated from the performance, and cannot be expected to do justice to its artistic requirements. If there is such a lack, it is usually because he has failed to appreciate his dependence upon facilities for smoother rendition of the show. Certainly the average exhibitor will take steps to provide such equipment, when its importance is pointed out to him.

VOLUME LEVEL

One other matter which bears in the same direction, is the tendency to feed excess volume into the house. Probaby more performances are spoiled through the bad reverberation and echo effects introduced thereby, than by any other single factor. The projectionist should fix a level for house conditions of half to full occupancy, and a lower level for empty to half-full house. The sound at these levels should just be comfortably heard throughout the body of the house under both conditions; if anything, the errors should be made on the side of too little, rather than too much volume. The proper amount can, with practice, usually be accurately gauged on the basis of the empty-house rehearsal of each production.

The mistake should not be made of trying to compensate for a few rows of seats in a bad area of the house where the sound is weak, by boosting up the volume to an extent where it interferes with the enjoyment of the patrons in the rest of the house. This is another very common error of practice. In such cases the problem is one of proper sound distribution, and a sound engineer should

be called in to remedy the difficulty.

In all the projectionist will realize that his skill in presentation of the performance is fully as important as that of the technicians who make the picture; in fact, he must be on his toes continually to guard against their errors of omission and commission. This phase of his work will lessen gradually perhaps, as the technique of the recording art is improved. But in the present state of affairs a large share of the responsibility for maintaining consistently smooth performances is his. To do complete justice to his job, he should have some grasp of the physics of light and sound, and should cultivate the sense of perspective which will enable him to judge the levels of sound necessary to reproduce the proper dramatic effects. The intelligent projectionist will, through study and correct practice, so equip himself. The improvement in his technique of presentation will be reflected in the added popularity of his theatre. Far-sighted theatre owners will not be long in recognizing this asset, and rewarding it accordingly.

BALANCING SOUND PROJECTORS

It is quite possible to have both projectors in first class condition yet both so out of balance that the entertainment is second rate. Assuming that the machines were correctly and carefullly matched at installation they still require frequent testing, for conditions sometimes alter in so short a space of time as a few hours.

When are two sound projectors balanced? Often the reply to this question states when they each give equal volumes from the stage horns. This is true only to a limited extent for there are many points to be considered besides volume.

The prime essentials that must be the same are: (1) volume; (2) quality; (3) speed.

Each one of these items includes both film and disc methods of reproduction. Secondary points which are almost equal in importance are: (4) scratch; (5) surface noise; (6) pickup amplifier tube response: (7) ground

noise; (8) photoelectric cells.

The true balancing of machines for volume is not so simple a matter as it may seem at first. A rough ear-test by the monitor will certainly indicate to within a few fader steps the matching but this is not good enough for first rate results.

Before any check for volume is made such projector should be thoroughly tested to ascertain:

(a) That both exciting lamps are in good condition; are carrying precisely the same current (checking the ammeter for zero error) and are both in exact focus.

(b) Both light gates should be cleaned and the lens should be polished.

(c) Photoelectric cells should be in good condition with clean windows.

(d) Plate batteries should not differ in voltage more than two volts.

(e) Pickup amplifier tubes should be carrying precisely the same filament current and give the same emission as checked for in the main amplifiers.

(f) Grid leaks should have clean connections.

(g) All film-disc changeover switches and rheostats should be clean and noiseless in operation except for the usual clean "plop" as they pass from one contact to another. There should be nothing gritty in their action.

(h) Pickups should be tracking properly and have the same drift and be fitted with two new needles of the same type.

(i) Both machines should be thoroughly run in before the test is started.

MATCHING FILM

It is quite common practice to match film by the hiss from the photoelectric cells. This is satisfactory so long as one knows by experience that the cells themselves give the same type of sound. In other words if the volume of the hiss is the same it may be assumed with fair certainty that the machines are matched. On the other hand if the

hiss of one is louder than the hiss of the other further tests should be carried out.

If the fader is equipped with a rapid changeover key it will be found very useful to use this instead of the main knob which takes appreciable time to swing from one side to the other.

Two test films must be used. To have only one is almost useless for the ear cannot retain a record of sound intensity for more than a fraction of a second.

The only true way of making a correct balance in volume between both machines on film and disc is to have four copies of the same subject, two on film and two on disc. Then, whichever way the fader is thrown, and whichever way the transfer switch is pushed, the same sound should come over the stage horns.

After the machines have been threaded they should be started simultaneously. To effect this, cord may be connected to the switch of the far machine for it is imperative that one hand set them off. Two persons are bound to make the movement out of phase. As mentioned previously the machines should be thoroughly run-in before the test. The reason for this is that before the oil has been warmed up, experience shows that one machine is almost certain to be slightly tighter in the bearings than the other, and thus will get out of step.

CHECKING VOLUME

An observer in the hall is often used for checking volume. This is all right so long as the telephone signals are not misunderstood. A better way is to listen from one of the ports which should have the glass removed for the purpose. If the nonsychronous set is near the booth this often affords a very good point of vantage for the observation of tests.

When the volume is matched the quality may still be at variance. An experienced ear will soon detect any difference in frequency response. A common source of trouble is a thin coating of grease over the focusing tube. Tests show that this will greatly reduce the high-frequency response.

Again, faulty tubes or badly matched tubes will sometimes give equal volume but quite different quality. On occasion photoelectric cells behave in a similar manner.

The speed of both projectors must be exactly the same. This may appear a curious statement when most of the better class sets are so governed that speed fluctuation is almost impossible. But the degree of similarity required in speed is extraordinarily high—so high in fact that an ordinary tachometer or revolution counter is useless for testing.

The ear of the ordinary observer will not be offended if the disc runs at thirty revolutions per minute instead of thirty-three and one-third. But at changeovers the thing is different. If the projector thrown in runs the smallest percentage lower in speed than that cut out the whole effect falls flat for the space of a minute or so until the ear becomes accustomed to the new key.

The only satisfactory practical method of checking machine speeds is by use of constant-frequency discs. Reproducers should be set on the same note and the fader operated. The sensitivity of this test it phenomenal and is increased if the power to the motor is cut on and off so as to give a rising and then a falling note.

Another useful method is to set both machines running and then manouvre coins or similar marking gadgets on the turntables so that they each pass a definite point together. Note the time and let the machines run for a few minutes. Almost certainly one table will creep ahead of the other and a simple calculation will give the exact percentage.

If both equalizers, or scratch filters are set similarly there should be no trouble on this account. Nevertheless it is wise to make sure that no connections have come loose and are making intermittent contact. Scratch, which is more or less inevitable at the present stage of development is not particularly objectionable so long as it does not vary in intensity.

Surface noise chiefly depends upon the copy but it is noticed that one cell sometimes gives worse results than another.

WIDE-RANGE REPRODUCTION

The purpose of any sound reproducing system in a theater is to enable the sound portion of a talking picture to be reproduced in such a manner that the full dramatic effects desired may be produced in the audience. In the early days of sound pictures there were two distinct limitations that prevented the system from completely fulfilling this requirement: first, a limited frequency range; and, second, a limited loudness or volume range. While there were, of course, other forms of distortion present they were, in most instances, of less commercial importance than the two just mentioned. From an engineering standpoint these older systems might have been termed "restricted-range systems."

In contrast to these are the "wide-range" systems with which this chapter deals and in which both frequency and volume ranges have been very considerably increased. We now have a system, the range of which is adequate to reproduce all the qualities of the human voice and falls much less short of complete reproduction of an orchestra than did the older systems.

It is obvious that an effective extension of the volume and frequency range provides the picture director with a tool that will greatly assist him in bringing out inflections and qualities of the voice that were before largely, if not entirely, lost. Likewise, the extension of the volume range provides him with a means for achieving dramatic effects which before could be only approximated.

With reference to the extension of the frequency range, the data usually presented take the form of a steady-state frequency characteristic. Attainment of a satisfactory curve of this kind is, however, not the only requirement, and it might be interesting to point out some of the factors that are important to good performance. While it is certainly requisite that all the components of each sound shall

be reproduced in their correct amplitudes, it is also desirable that the sound shall be reproduced with the right duration. Resonant elements introduce transients, recognized as a prolongation of some sounds beyond their natural duration, so that they overlap the following sounds, thus distorting quality. In the present advanced state of the art this is not often so in the electrical design. Such prolongation occurs occasionally in the case of loud speakers of inadequate design and frequently in auditoriums where the backstage area permits marked standing-wave patterns. Such effects impair the performance of the best sound systems.

A further requirement of the system is that there be no non-linear distortion, which distortion is evidenced by the introduction of components that are not present in the original sound. In other words, there must be a linear relationship between the amplitude of the input and that of the output in all parts of the system.

This leads naturally to a consideration of the power output of the amplifier necessary to supply auditoriums of various sizes. A considerable amount of work has been done along this line which makes it possible to set the amplifier requirements rather definitely.

The question of the power required for wide-range reproduction is rather interesting. If a system already installed be modified to permit wide-range reproduction without consideration of the amplifier power capacity, well recorded music will sound slightly louder than it does on the standard system. On the other hand, the improvement in naturalness, brought about by extending the range, leads one to feel that he is listening to the orchestra itself rather than a reproduction of it, and the immediate reaction is a feeling that the loudness is insufficient. It is interesting that this improvement in quality appears to transfer the mind of the listener from an artificial standard to the standard of real original performance. In view of this effect, it has been found desirable to increase the power capacity available for the wide-range system as compared with the old standard system. In theatres already equipped with systems of the old type, observations were made to determine the adequacy of existing amplifiers before the wide-range

modification. It was found desirable in many cases to modify or replace the amplifiers. In theaters not previously wired for sound, higher powered amplifiers than would normally be employed in restricted-range systems were installed.

Wide-range systems appear to have sufficient power to reproduce adequately anything now recorded upon, or likely to be recorded upon, film in the near future. Whether or not they have sufficient reserve to meet any future demand is, of course, impossible to foretell accurately.

ACCURATE ADJUSTMENT OF EQUIPMENT

In order to attain the greatest dramatic effect from this improved equipment, it has been necessary to develop a very definite technique of installation. The procedure is of importance, first, in coordinating the operation of the various parts of the equipment, one with another; and, second, in acoustically draping the backstage space to avoid standing-wave interferences.

As a preliminary to the description of this procedure, a brief statement regarding the equipment may be of interest. The equipment consists, essentially, of the sound-head for translating the sound-track into electrical impulses, an amplifier system to amplify these weak impulses, and a loud speaker system to translate the electric currents back into sound. The main part of the description will deal with the loud speaker equipment, although it has been necessary to make improvements in all parts of the system in order that it may be capable of transmitting to the loud speakers the increased volume and frequency range.

The loud speaker system differs materially from the earlier commercial theater types mainly in that there are three sets of loud speakers, one for the low frequencies, one for the mid-range, and one for the extremely high frequencies. In addition to these three sets of speakers, a network is necessary for splitting the output current of the amplifier into three frequency-bands, one for each set of loud speakers. The ranges covered by these three sets of speakers, are approximately as follows: Low-frequency set, up to 300 cycles. Mid-range set, 300 to about

3000 cycles. High-frequency set, 3000 cycles and up.

It will be seen from a consideration of this type of system that a definite problem is found in arranging the system to avoid bad interference within the frequency ranges in which the various sets of loud speakers overlap. This is particularly true because the electrical network that divides the amplifier output into the three frequency-bands is not of the sharp cut-off type, and therefore permits considerable overlapping of the various sets of speakers. The sharpness of this cut-off, in a commercial system, is of necessity a compromise between expense and effectiveness. The sharpness afforded by this system has been found adequate for good quality provided the proper installation procedure is followed.

INSTALLATION TECHNIQUE

The special installation technique is carried out for the purpose of insuring that the various parts of the reproducing equipment cooperate properly with one another. This technique has naturally divided itself into the following series of operations:

(1) Acoustic diagnosis of theater auditorium.
(2) Positioning the mid-range horns to afford best sound distribution.
(3) Positioning and volume setting of the low-frequency units.
(4) Diagnosis and acoustic treatment of backstage interferences.
(5) Positioning and volume setting of high-frequency units.
(6) Final check of system on commercial product.

ACOUSTIC DIAGNOSIS OF THEATER AUDITORIUM

If expense were no object, the acoustic diagnosis would be made with measuring instruments. However, it is frequently impractical to make the necessary measurements, and under such conditions the reverberation time and its frequency characteristic are computed from a survey of the size and shape of the auditorium and from the nature

of the floor, walls, seats, hangings, etc. This reverberation time becomes the starting point of the theater analysis.

In the application of the wide-range systems to the theater, there are other acoustic properties besides the average reverberation time which are of great importance. Again, for practical reasons, these effects have been divided into two groups: those caused by the front-stage sound in the auditorium and those caused by the conditions backstage. All discussion of the backstage troubles will be left until later, and the present discussion will deal only with the frontstage effects.

These special effects refer to concentrated reflections from large, flat, or curved surfaces, such as the back wall, a curved ceiling or dome, the front of a deep balcony, etc. As is well known, the reverberation time for satisfactory reproduction lies between two limits which are rather widely separated. In practice, very few houses, if any, are found to be too dead. Therefore, it has been customary to specify these limits as the time of reverberation for optimal reproduction and as the maximal time of reverberation acceptable for commercially good quality. In addition to determining the reverberation time, which is an index of general liveness, the acoustic analysis determines the presence of echoes, "slaps," multiple reflections, etc., from undamped, curved, flat surfaces. In theaters having such defects, which have not been corrected by acoustic treatment, careful diagnosis by ear, after the system has been installed, frequently permits positioning the loud speakers to minimize the defects. Such diagnosis consists in exploring the whole audience area by ear while reproducing some form of speech with the loud speakers on the stage. It has been found possible, under these conditions, to locate the so-called "slap" or echo areas; and, in most cases, a visual inspection of the position of the sound-source, the slap area, and the geometry of the house leads immediately to detecting the sound path causing the difficulty. However, a considerable amount of skill is involved.

POSITIONING HORNS

The next step of the procedure, therefore, is to position

the mid-range horns in such a manner that their sound is distributed to the audience area without bad interference from echoes and slaps. In the majority of houses, the reverberation time of which lies within acceptable limits, this is possible without additonal acoustic treatment. Since the horn speakers are directional to a large degree, it is possible to direct the sound into the audience area in such a manner that very little direct sound from the horns reaches the troublesome reflecting areas. Naturally, in the case of a curved back wall, it is necessary either to sacrifice good sound in some of the back seats or to apply acoustic treatment to the wall immediately above the heads of the audience.

Since the majority of theaters have a higher reverberation time than optimal, and are, therefore, livelier than desirable, the technic of avoiding "slap" by concentrating the sound upon the audience area has automatically introduced an improvement, namely, an apparent decrease in the reverberation of the house. Because the ear interprets the liveness of a reproduction by the ratio of the time integral of the reverberant sound to the intensity of the direct sound, any means of increasing the direct sound or of decreasing the reverberant sound tends to decrease the liveness. By concentrating the direct sound from the horns upon the audience area, a maximum of direct sound is attained at the listener's ear. In addition, since the audience usually constitutes the most effective damping in the theater, the reflected sound that finally reaches the livelier part of the theater, to become reverberation, is thereby decreased. For both these reasons, therefore, a house can be made to appear under reproducing conditions, deader than it would be for a real performance for which most of the sound sources are relatively non-directional. This is one of the reasons why the maximal acceptable time of reverberation is as high as it is for reproduced speech.

One interesting effect has been noticed in connection with setting the horns, namely, that a much more accurate setting can be obtained by so positioning them, initially, that they definitely include the error to be avoided. They are then angled or moved slightly until this error disappears. This implies that the ear can more accurately deter-

mine the removal of an error than the approach to it. Whether this would be true if the recording and its reproduction were perfect is not known, but it is certainly true under the present practical conditions.

VOLUME SETTING OF LOW-FREQUENCY UNITS

Now that the horns have been properly set, the next step of the procedure is the addition of the low-frequency units. The effect of improper relationship is easily noticed, was looked for between the lower-frequency and mid-range units, and an effect was found that was mistaken for a real phase relationship. Later work, however, indicated that this effect had many properties that did not agree with real vector phasing, and the exact nature of the effect is not completely known. The presence of real vector phasing is audible, but the slight change of quality brought about by it is neither disagreeable nor is it noticeable to the majority of the public. On the other hand, the important effect, that is, the one previously mistaken for real phasing, produces a marked difference in quality according to the correctness or incorrectness of the geometrical and electrical relations between the mid-range and the low-frequency units. The effect of improper relationship is easily noticed, and is disliked by the majority of the public. In the so-called unphased conditions, the sound is distinctly disagreeable; whereas in the so-called phased position, it is said by the layman to be pleasing to listen to.

It has been found for a horn of a given length there are a series of fore and aft positions at which the baffle may be placed for good quality. This is on the assumption that the mid-range and the low-frequency units are electrically poled identically; that is, that the current supplied to them produces, in both sets of units, movements of the diaphragms in the same direction. If the polarity of either set of units be reversed, a new series of positions are found for the baffle half-way between the points lying upon the previously mentioned series. It is no wonder, therefore, that this effect was mistaken at first for vector phasing.

In the early technic, loud speakers were set to reproduce correctly for a point on the floor of the house, and

the balcony was regarded as of secondary importance. However, in several installations where two observers were available, one was placed in the balcony and one on the floor of the house. It was surprising to find that both these observers chose the same phrasing positions in spite of the fact that in some cases the observer in the balcony should have been in a position 180 degrees out of phase with the position of the observer on the floor. In other words, this effect is not a real sound-vector phasing effect, but appears to have something to do with the diffraction pattern set up about the top edge of the baffle and the bottom edge of the horn. This is further corroborated by the fact that the so-called phasing position is independent of the vertical distance between the lower edge of the horn mouth and the top edge of the baffle.

ACOUSTIC TREATMENT OF BACKSTAGE INTERFERENCES

The backstage acoustic difficulties are brought about mainly by the radiation from the back of the low-frequency units and by the mid-range sound reflected into the backstage area by the screen. This sound is reflected from the various walls of the backstage area, and some of it returns to the units in such phase relation as to add to the sound then being radiated. Under these conditions marked standing-wave patterns are set up. The commonest, and usually the most marked, of these patterns is that existing between the low-frequency units and the rear stage wall. In order to minimize this pattern the baffle is usually inclined slightly with respect to the vertical in such a manner that the sound returning from the back wall and striking the baffle is reflected slightly upward, thereby avoiding a sharp standing-wave pattern between two hard, parallel surfaces. In spite of this precaution, a rather severe pattern is usually set up, and acoustic absorption material is necessary to counteract its bad effects.

It is well known that acoustic damping material is most effective in a standing-wave pattern at the position where the air particle velocity is greatest. This position on the wave is the position of minimal sound to the ear, since the maximal velocity position is the position of minimal pres-

sure variation.

In order to diagnose the position of this velocity maximum it is necessary only to move the head slowly from the back wall to the baffle while the system is reproducing male speech. During this procedure the positions are noted at which the so-called "boominess" of the sound is least. These positions of least "boominess" are the points at which damping material will be most effective. From a commercial standpoint it is fortunate that the minimum nearest the baffle is usually the sharpest one, and, therefore, constitutes the most effective position for the draping material.

The draping material used is unimportant, provided that it is soft and flexible and has an absorption equivalent to Ozite, ¼ to ½ inch thick. Two thicknesses of heavy velour spaced one inch apart have been found quite satisfactory.

Having found the proper position for the drape, which is usually called the main drape, it is hung immediately. It is now necessary again to explore the backstage for additional standing-wave patterns which sometimes arise between the low-frequency units and the sidewalls or between the low-frequency units and the ceiling. With the main drapes in place, it is occasionally found that the sound, as heard in the auditorium, either lacks "presence," that is, appears to come from some distance behind the screen; or that it seems as if considerable non-linear distortion were present. Under these circumstances it is necessary to explore the backstage area, particularly the region between the bottom of the horn mouths and the top of the baffle, for the presence of patterns. This is done, as in the previous case, by moving the head slowly about in this area while speech is being reproduced. In this case, instead of getting sharp maxima and minima of intensity, a condition is found in which the head moves from a region of badly garbled speech to one of relatively clean, clear, intelligible speech. As before, drapes should be hung at the position of least garbling; in other words, at the position of maximal clarity.

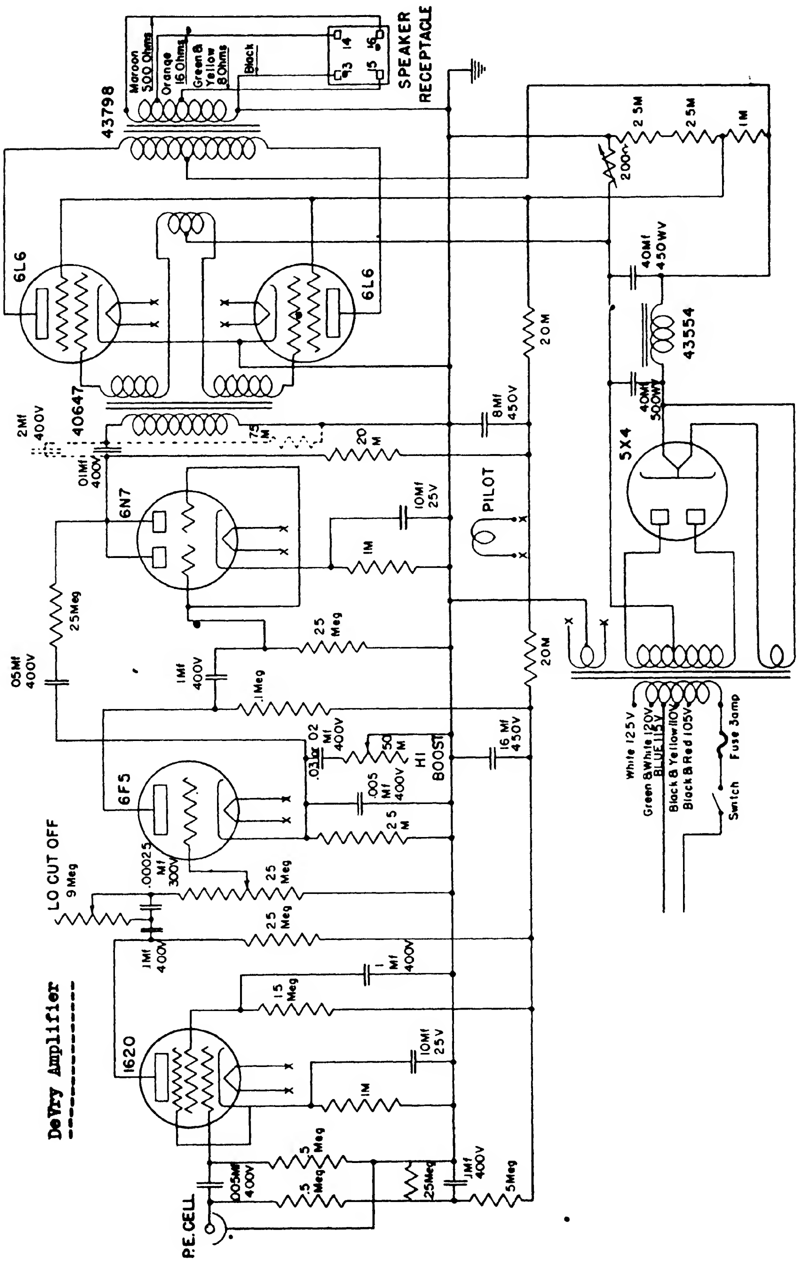
The importance of careful backstage draping can not be too vigorously stressed, because most of the troubles of the early installations of wide-range systems were brought about by complicated backstage patterns. These troubles were mainly removed when this pattern was properly diag-

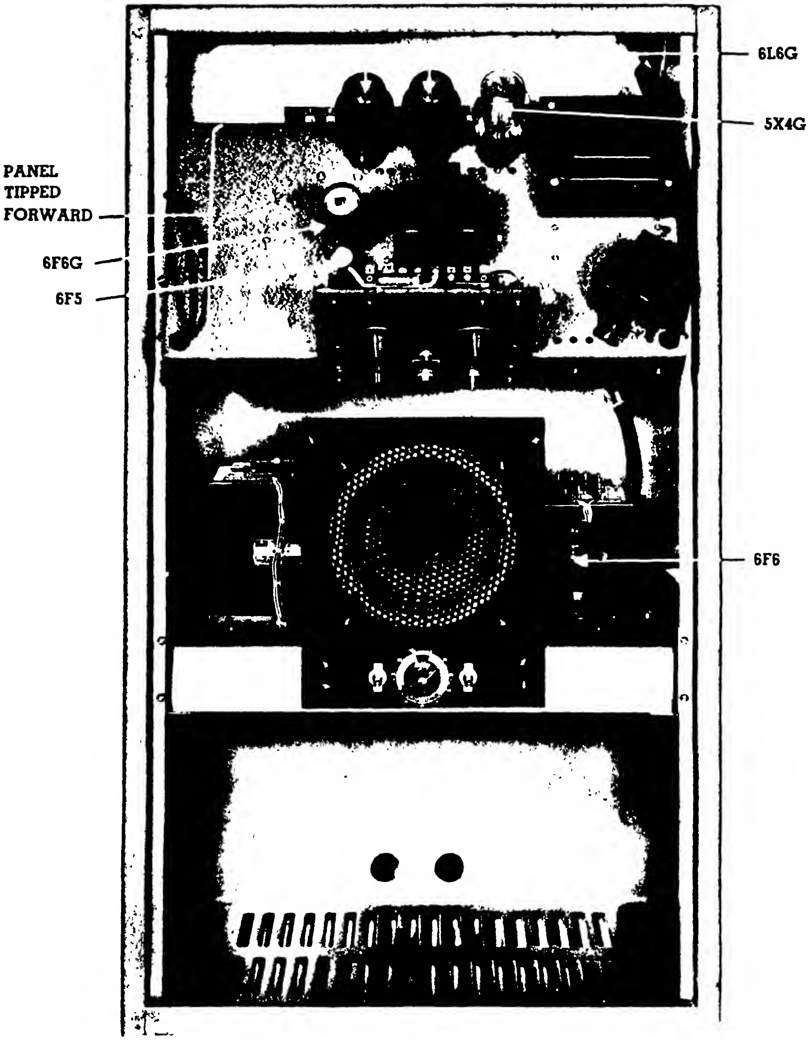
nosed and the necessary drapes hung.

VOLUME SETTING OF HIGH-FREQUENCY UNITS

It will be seen that up to this point the system has been operated without the high-frequency units, and that it is ready for commercial use except for the addition of these units. It has been found by experience that the positioning technic for these is similar to that for the baffle with respect to the mid-range units. The positioning of the high-frequency units is of great importance as regards the quality that will be obtained from the system. The high-frequency units show a definite series of fore and aft positions, with respect to the mouth of the mid-range horns, at which the sound quality is pleasing. If the polarity of the high-frequency units be reversed, a new series of positions are found lying halfway between the positions of the first series. This is a rather startling result, because the air-path difference to the screen from the diaphragm of the mid-range units and from the diaphragm of the high-frequency units is frequently as great as fourteen feet. This distance corresponds roughly to forty times the distance between the positions at which the high-frequency units sound good. Since the dividing network is not of the sharp cut-off variety, there is considerable overlap between the mid-range and high-frequency units and it is readily seen that this positioning effect can not possibly be real vector phasing.

Having positioned the high-frequency units by ear during the reproduction of an adequate test-film, the only remaining step is to regulate their intensities so that they blend properly with the rest of the reproduction. With this done, a final check is made with the commercial product available in the theater.


DeVry Amplifier
SPEAKER RECEPTACLE
Maroon 500 Ohms
Orange 16 Ohms
Green & Yellow 8 Ohms
Black
43798
6L6
6L6
40647
6N7
6F5
1620
5X4
43554
PILOT
HI BOOST
LO CUT OFF
P.E. CELL
White 125V
Green & White 120V
BLUE 115V
Black & Yellow 110V
Black & Red 105V
Fuse 3amp
Switch


6L6G
5X4G
PANEL
TIPPED
FORWARD
6F6G
6F5
6F6

Set projector head on the base mounting rails and tighten in position with the mounting bolts furnished with the base.

The upper magazine is then mounted to the projector frame by fitting the support bracket of the magazine over the threaded studs located at top of projector frame, and screwing the knurled nuts onto the studs. See A in Plate V-60.

Arc brackets are then fastened to projector head and base. The leveling adjustment screw is fitted to the base and the bottom bracket support pin inserted through the top of the adjustment screw.

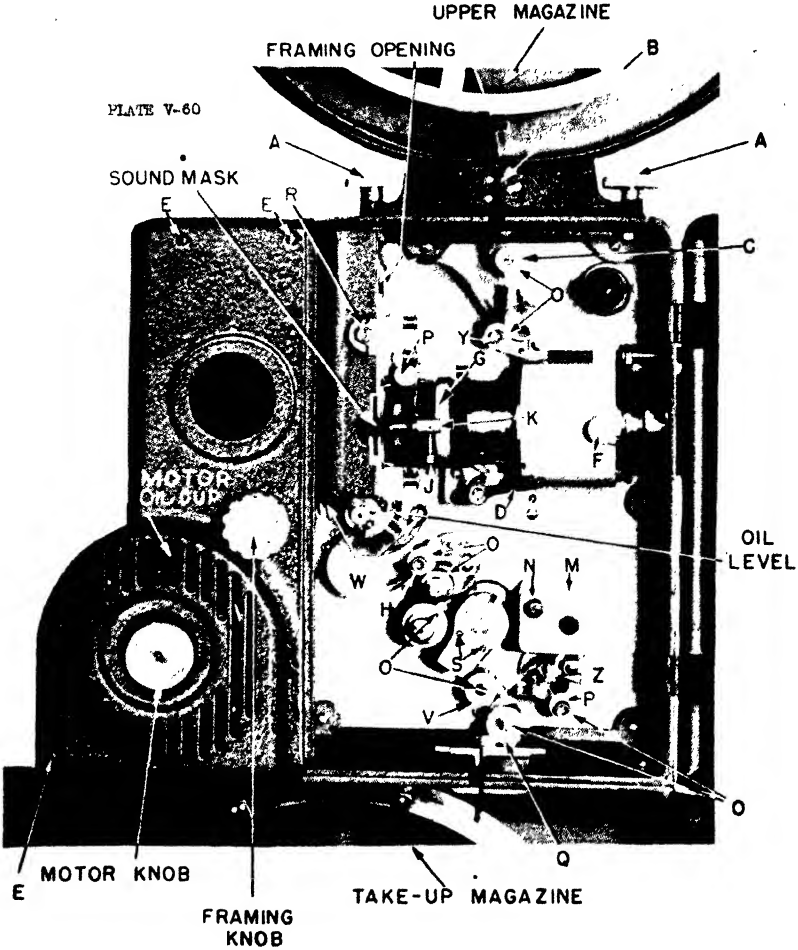
Affix the framing knob, Plate V-60, which is packed in an envelope inside the projector head, into position on the framing shaft. Tighten set screw thoroughly.

The arc lamp is then placed upon the arc lamp table in line with the slots and secured in position with the lamphouse mounting bolts provided.

Where the two tube rectifier is used (low intensity arc lamps), the two asbestos covered arc leads are connected to the D. C. output of the rectifier (observing polarity). The 115 volt, 60 cycle, single phase A. C. line connects through the square D or knife switch on the lamphouse bracket so that only the primary line is broken.

Where the four tube rectifier is used (intermediate high intensity or Suprex arc lamps), the two asbestos covered arc leads are connected to the D. C. output of the rectifier. The 220 volt line connects through the contactor in the rectifier and a toggle switch on the lamphouse bracket serves as a remote control switch for turning rectifier ON and OFF.

PLATE V-60


UPPER MAGAZINE
FRAMING OPENING
B
A
A
SOUND MASK
E
E
R
C
O
P
Y
G
K
F
J
D
MOTOR OIL CUP
OIL LEVEL
O
W
N
M
H
O
S
Z
P
V
O
Q
E
MOTOR KNOB
FRAMING KNOB
TAKE-UP MAGAZINE

Where rheostat is used, connect the two asbestos covered arc supply leads to the arc cut-off switch (observing polarity). Then, connect one end of the 110 volt D. C. line to the arc cut-off switch. The other end of the 110 volt D. C. line connects through the arc lamp rheostat to the arc cut-off switch.

Conduit providing 110 volt 60 cycle A. C. power for operating the exciter supply and the projector motor is then connected to the projector. Plate U-61.

Adjust lens for sharp focusing. This necessitates striking the arc, turning motor switch ON, turning dowser ON.

To strike the arc, give the lever which projects underneath the right hand door of the arc lamphouse a quick sift toward the rear of the lamphouse and letting it drop back to normal position quickly.

With the projector running and light being projected on the screen, adjust lens for sharpest focus by loosening lock stud F, Plate U-60, and move lens forward or backward by means of the Lens Focusing Knob, 15 in Plate U-63, until the projected image is distinct on the screen. Then, tighten lock stud F. Plate U-60.

Projector base is finally tilted for correct picture location. To do this, loosen the adjustable side clamping wheels and raise base to position desired, then lock in place.

Follow the same procedure for both projectors. Operate both machines at the same time and adjust lens focus on one or the other until projected images coincide on the screen.

After the projectors have run a few minutes, it is a good plan to stop them and place a few drops of oil in all oil holes, Plate U-60.

Also, check to see if driving chains are of correct taughtness.

Holes are then spotted into floor through the four base lugs. Projector is then set aside and holes drilled for 5/16 inch anchor bolts or lag screws depending upon individual circumstances. Final adjustments for centering picture on screen are then made and bolts

tightened.

The amplifier wiring to the projector, as well as to the automatic dowser wiring, should now be completed.

The dowser floor switches (9 in Plate U-64) should be fastened in convenient operating position below observation port and wired into position with BX or Greenfield. See Plate U-64 for suggested arrangement.

The speakers should then be definitely located so that the high frequency element faces the screen at two-thirds of the height of the projected picture. A wooden or steel platform should therefore be constructed around this height dimension.

Speaker wiring should then be completed.

Where D. C. field coil speaker units are furnished, the speaker field supply for energizing the loud speaker field is located in the amplifier.

In this type of installation it is customary to connect five Number 12 wires from the amplifier speaker terminal strip to the terminal strip in the speaker system, connecting wires to corresponding numbers on each strip, as No. 2 wire to No. 2 terminal, and so on.

Where permanent magnet speakers are used, three Number 12 wires are connected between the amplifier speaker terminal strip to the terminal strip in the speaker system, connecting wires to corresponding numbers on the terminal strip as No. 2 wire to No. 2 strip, and so on.

THREADING THE PROJECTOR

A diagram showing the correct method of threading the projector and the soundhead is shown in Plate V-65, also refer to Plate V-60.

First, snap switch located at the rear of projector, Plate V-62, marked Pilot Lamp to ON position. Then place reel of film into the upper magazine, with emulsion side of film toward arc light source, and draw out 6 to 8 feet of the film leader and pass it between the fire rollers "B," Plate V-60. Pass it around the rear or left side of roller "C" and between the idler and feed sprocket as shown in Threading Chart. The idler

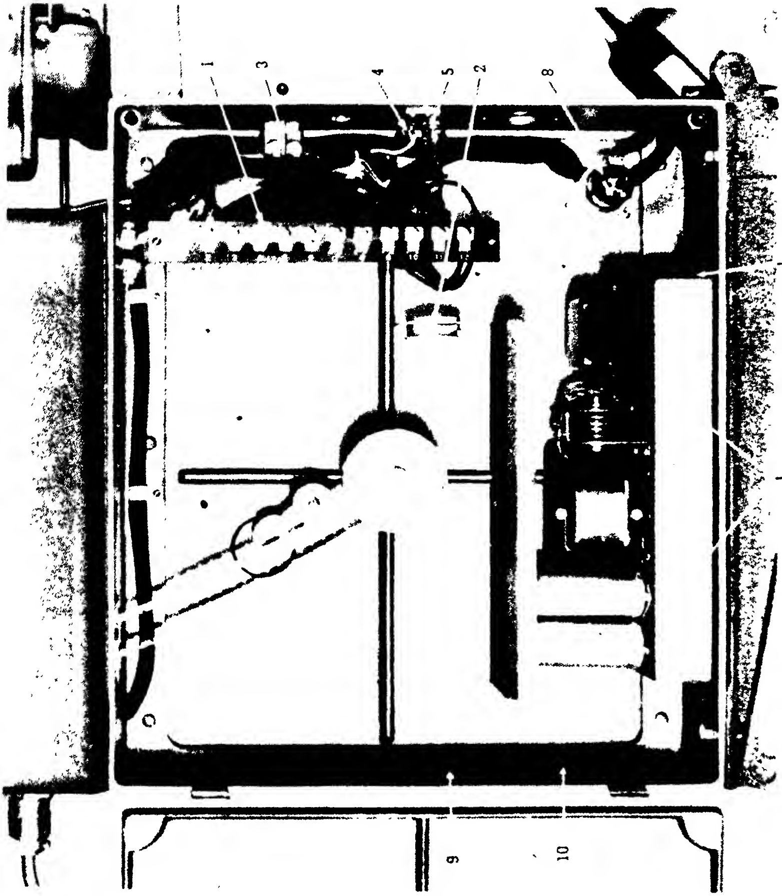
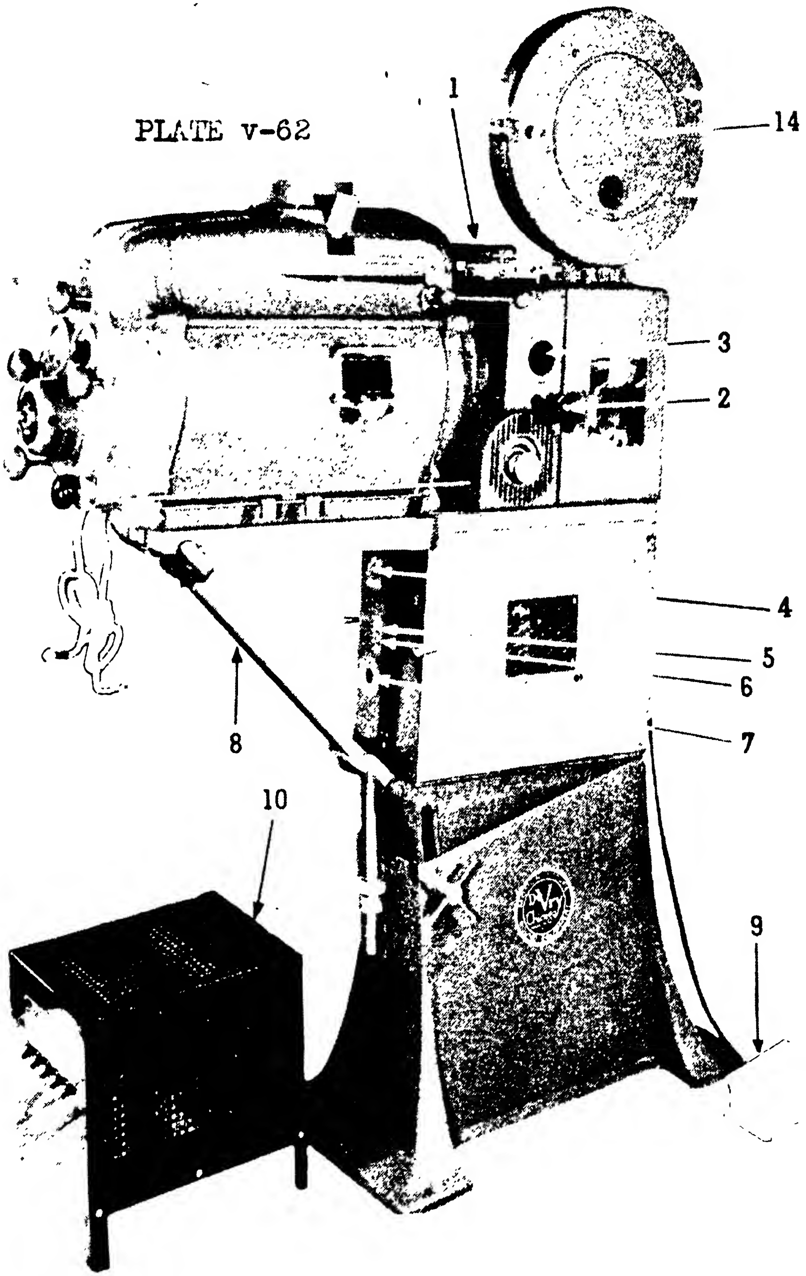


PLATE V-61

PLATE V-62



is opened by pulling out on the knob "Y" and pushing the idler downward away from the sprocket. To close idler after the film is in position, merely push it into place against the sprocket where it automatically locks into place. Make sure the film perforations are fully engaged by the sprocket teeth.

The aperture gate is then opened by raising lever "D," Plate V-60. Lay the film in place in the aperture, making sure that it is between the guide rollers at the top of aperture plate and engages the intermittent sprocket to the bottom of aperture plate. Upper film loop to be approximately the same size as shown in Plate V-60. Hold film in this position and close aperture gate by lowering lever "D." The film is next brought between the hold-back sprocket idler "H" around the sound adjustment roller, over the sound drum, under the floating roller "V," around the sound sprocket at "Z" and locking idler "P," over stationary roller "Q," between fire rollers and into the take-up magazine.

Fasten film to hub of take-up reel and turn in a clockwise direction. Now check threading by turning motor knob, Plate V-60, clockwise. If this knob turns freely and film is not under undue strain at any point, the projector is properly threaded.

The next step before operating projector is to see that "film is in frame." This phrase means having one complete picture at the aperture opening before projecting pictures on the screen. Check this by holding film with one finger against aperture plate at opening above guids rollers, Plate V-60, and observe whether one complete picture is covered at this point. If not, turn framing knob, Plate V-60, until it is so covered. Then turn the pilot lamp switch off.

AMPLIFIER

To operate the sound reproducing unit at the start of a performance, turn the main A. C. supply unit switch ON. This energizes both the projector and the sound equipment.

Snap the amplifier and field supply switches

(where used) to the ON position. Plate V-66.

Push the dowser manual control IN. Plate V-66. This will close the light aperture.

Turn the exciter and pilot lamp switch ON.

Adjust the volume control on the pre-amplifier to a setting of 20, which should be normal for most film.

The projector will operate when the DOWSER FOOT CONTROL, 9 in Plate V-62, is depressed. This energizes the exciter supply in the machine as well as lifting the dowser shutter. Sound should then be reproduced from the main speaker system.

SPEAKER FILTER DIVIDING NETWORK

Switches are located on the speaker dividing network (Plate V-66) which disconnect the stage speakers in the event it is desirable to use the projection equipment in conjunction with the monitor speaker for testing purposes. In order to operate the equipment with the stage speaker, be sure that the high and low frequency speaker switches are in the ON position.

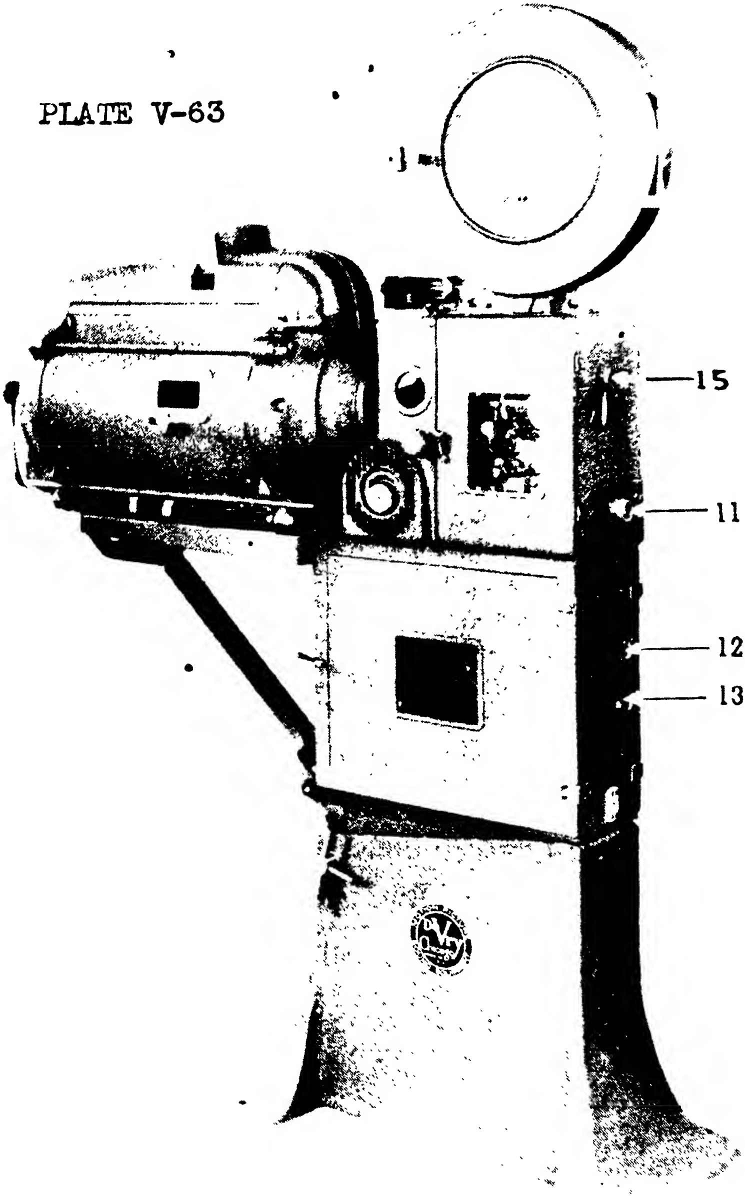
FREQUENCY CORRECTION CONTROLS

Frequency correction controls are located on the front of the main amplifier and allow 35 different reproduction characteristics to be selected. Plate V-66. These will be found most convenient in adjusting the reproduction characteristics of the system to match the acoustical capabilities of the auditorium.

AUTOMATIC DOWSERS

The automatic changeover supply operates on a solenoid principle, two coils being used for its operation, one of them supplying the opening impulse to the mechanism, the other supplying the closing impulse. A flexible drive is used between the solenoid armature and the aperture shutter which slides on rails and is mounted directly behind the aperture plate. The sound section of the changeover is a make-break switch system which functions in conjunction with the exciter supply.

PLATE V-63



DOWSER INTERCONNECTIONS

The closed coil of one machine is paralleled across the open coil of the other machine and, therefore, when the foot switch of the projector is depressed, the projector is energized as to sound and the dowser shutter opened. The dowser on the second projector operates in a reverse manner, the shutter being closed and the exciter supply disconnected. Speed of the dowser opening and closing operation is determined by the adjustment bolt on the top of the dowser case which places a tension on the solenoid shaft.

MONITOR SPEAKER

The monitor speaker is mounted with the speaker dividing networks, (Plate V-66), with a volume control between the stage speaker switches. The monitor takes power as well as voice signals from the main amplifier. The volume of the monitor is dependent on the pre-amplifier volume control settings.

MAINTENANCE OF PROJECTORS

The most important contributing factor to perfect pictures is the proper care of the equipment. Cleaning and oiling the mechanism every day, if the projector is run continually or if a period of two or three weeks lapses between each operation of the machine, oiling before each show is the most positive way of avoiding interruptions during operation.

INTERMITTENT

While the intermittent unit is of rugged construction, it is likewise a unit assembled with meticulous accuracy and is a most vital part of the projector mechanism. It is highly important that the oil level be maintained at all times with the proper lubricant. (Plate V-60). Never use a heavy grade of oil or an oil containing graphite in the intermittent oil system. A heavy grade of oil will not penetrate into the finely fitted bearings of the unit and will result in a "freeze up." The use of a graphite oil is equally dangerous as the graphite acts like an abrasive on the fine pre-

cision parts and causes undue wear in a short period of time. Therefore, it is of great importance that a lubricant of 140-145 viscosity be used. Drain oil well after each 100 hours of operation.

DRIVING MECHANISM

On the driving side of head (Plate V-67), the points indicated should also receive occasional oiling. The chains should be given a very limited amount of oil.

APERTURE ASSEMBLY

The aperture film shoes assembly is easily removed for cleaning. Unscrew knurled tube "G," and slide tube against lens holder or towards the front of case. Open the aperture by turning lever "D," loosen knurled thumb screw "P" and pull film shoe assembly straight out. The film shoe assembly, the rails and aperture plate may then be quickly and easily cleaned. To reinsert the film shoe assembly, slide bracket over the rod and tighten knurled thumb screw. After a few attempts, it will become a matter of seconds to clean the aperture assembly completely. When cleaning aperture and film shoe, use soft cloth saturated with oil.

ADJUSTING TENSION OF FILM SHOE

The tension springs on the film shoe are meticulously adjusted before leaving the factory to accommodate new, old or oily prints. This precise adjustment minimizes the wear on the sprocket guide rails and on the film itself and assures a rock-steady picture. However, the tension on the springs can be quickly adjusted to meet any situation by merely releasing screw "J," Plate V-60, and turning knurled nut "K," upward to increase tension, downward to reduce tension.

ADJUSTMENT OF INTERRUPTING SHUTTER

If through some adverse condition the shutter loses its adjustment, or a traveling ghost appears on the screen, the shutter should be retimed. To do this, remove the framing knob, (Plate V-60), and the three screws marked "E," Plate V-60, which will release the

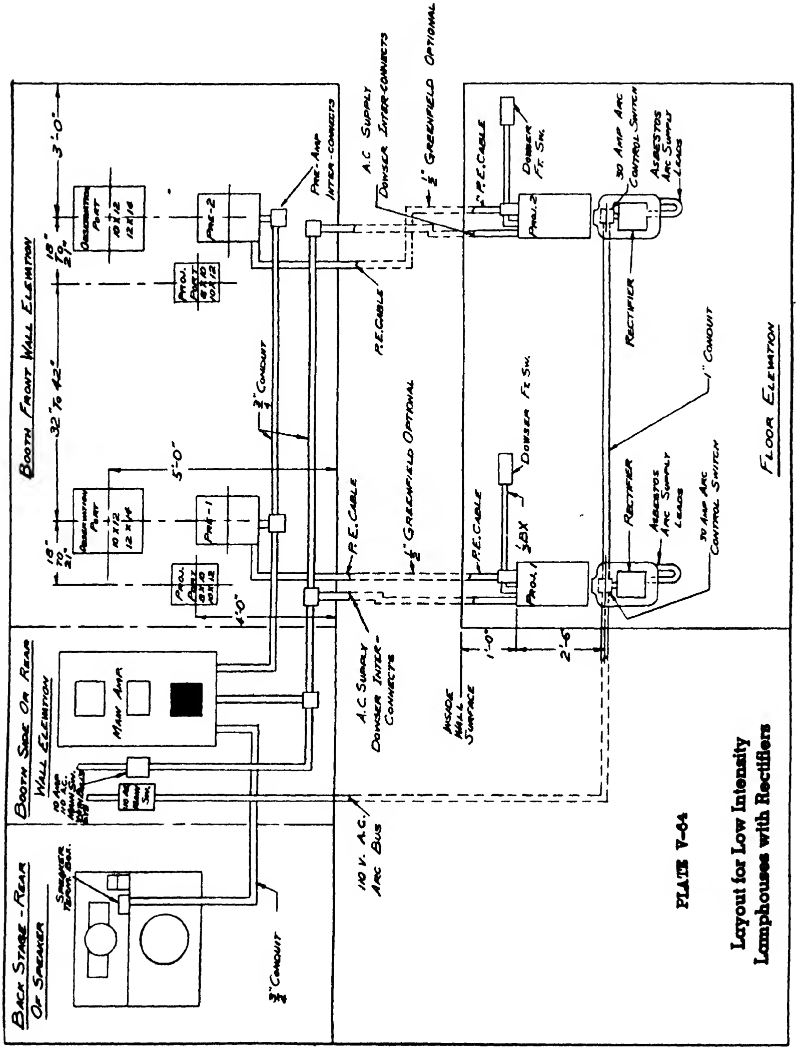


PLATE V-64

Layout for Low Intensity Lamphouses with Rectifiers

stationary door and expose the shutter assembly as shown in Plate V-68. Then, remove the two screws marked "A," Plate V-68, exposing the shutter drive gear. Next, loosen the large screw mounted to the drive gear slightly. (This screw has a left hand thread, therefore, to loosen turn screw driver to the right), and at the same time hold the shutter chain sprocket located on opposite side of assembly. Use a large screw driver to prevent damaging the screw. The shutter is then retimed by holding motor knob and turning shutter until the solid part covers one complete pull down of the film at the aperture. Then securely tighten the shutter gear screw and reverse the procedure as outlined above.

TO REPLACE EXCITER LAMPS AND PHOTOCELLS

The projector is equipped with a 6 volt 1 ampere prefocus exciter lamp. To replace this lamp, proceed as follows: Remove exciter lamp cover "M," Figure V-60, by loosening the knurled nut "N," Plate V-60, and grasp exciter lamp and turn in a counter clockwise direction until lamp is released. To mount new lamp reverse above procedure, after first setting the three large holes in lamp base over the corresponding pins of the exciter lamp socket.

To replace the photo-electric cell, remove the housing cover by unscrewing the two screws at "S" in Plate V-60: Place cover and screws aside so as not to misplace them. Then, grasp photo-electric cell with fingers and pull toward you. When inserting new photo-electric cell, be sure the three contacts of the cell line up with the socket holes before inserting into place. Then, screw housing cover into place.

TO REMOVE INTERMITTENT

To remove the intermittent unit, take the sound flywheel off its shaft by holding the flywheel and withdrawing the screw at "A," Plate V-67, and carefully pull the flywheel off its shaft. Next, loosen the drive chain from around the intermittent drive sprocket by removing the three screws at "B," Plate V-67, and

take the large chain sprocket off its shaft, thus loosening the drive chain. Looking at Plate V-60, loosen the two screws holding the intermittent luge at "W," and turn the lugs toward the center of the movement, then tighten screws again. The entire intermittent unit can now be removed by grasping intermittent flywheel, Plate V-67, and pulling it out of its mount.

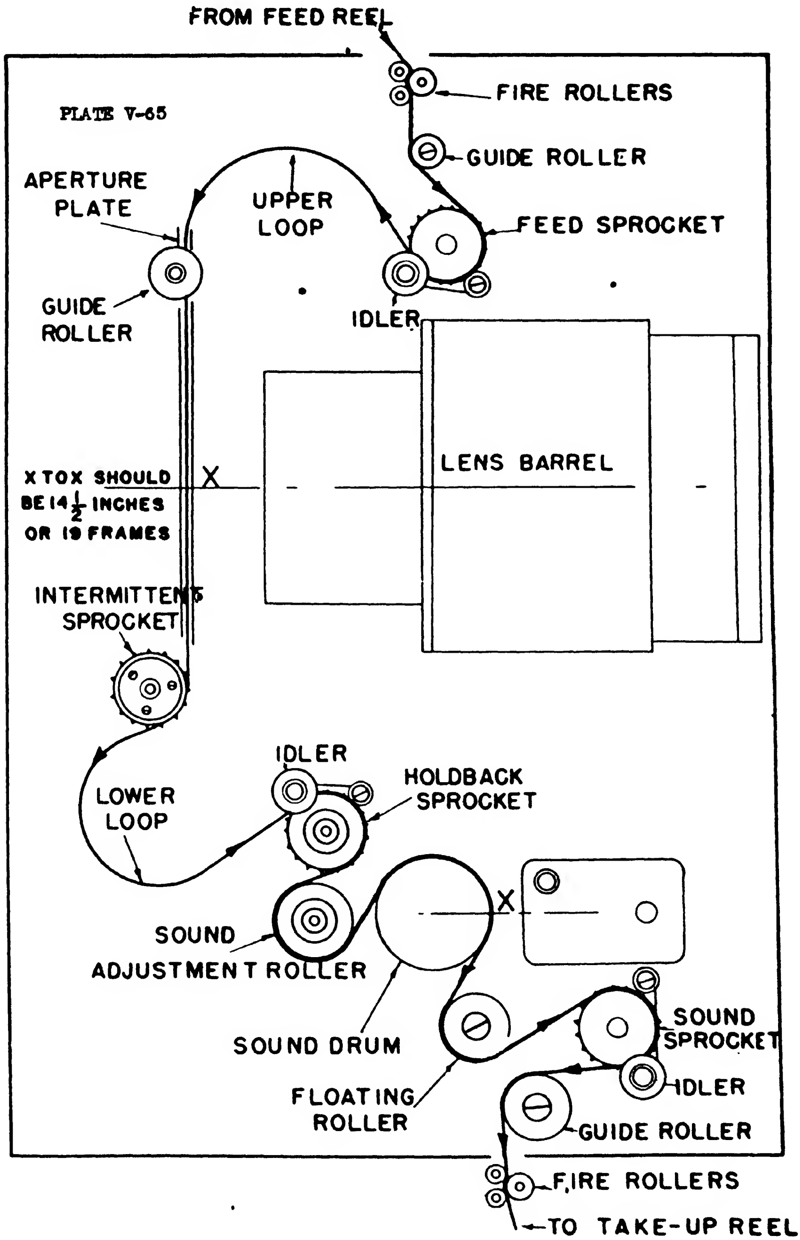
ASSEMBLING THE DOUBLE BEARING

If either of the bearings in the arm (inner or outer) are worn, they should be replaced. Next, the star shaft must be fitted to these bearings in much the same manner that the flywheel shaft and cam shaft were fitted. When this has been accomplished check the sprocket, making sure it has a good push-fit on the star shaft. If it fits too tightly, it should be opened slightly with the lap. The sprocket should absolutely not be forced onto the shaft. As these are very accurate parts, great care must be exercised that they are not sprung out-of-true.

After assembling the star in the bearings with the sprocket in place, place the aluminum collar on the end of the star shaft. After tightening this collar in place, the star shaft should turn freely and without end shake. Now the taper pin holes in the sprocket and star shaft must be reamed in line so as to allow the taper pins to seat properly and hold the sprocket firmly in place. A taper pin broach for this work will be found in the Spare Parts Box. The film stripper is put on last.

The arm is now ready to be assembled to the case. Place the cover and arm over the opening of the case and make certain the star head is turned so that it will not come in immediate contact with the cam. There is a hole provided in the cover arm which should be fitted over the dowel pin on the case. With this eccentric, adjustment can be made between the star radii and the cam. Before tightening the case cover screws, make sure the adjustment between the star and cam is such as to allow free action without shake.

The unit is now ready for the running-in period.


FROM FEED REEL
FIRE ROLLERS
PLATE V-65
GUIDE ROLLER
APERTURE PLATE
UPPER LOOP
FEED SPROCKET
GUIDE ROLLER
IDLER
LENS BARREL
X TO X SHOULD BE 14½ INCHES OR 19 FRAMES
X
INTERMITTENT SPROCKET
IDLER
HOLDBACK SPROCKET
LOWER LOOP
X
SOUND ADJUSTMENT ROLLER
SOUND DRUM
SOUND SPROCKET
IDLER
FLOATING ROLLER
GUIDE ROLLER
FIRE ROLLERS
TO TAKE-UP REEL

Place the assembled movement in the projector and allow to run for a period of three hours with the oil up to the oil line. If the unit is not assembled right or the parts misfit, it will be apparent during the break-in period.

SOUND SPROCKET

The sound sprocket can be easily removed by bending the stripper plate away from the sprocket, loosening the set screw located in center of sprocket, and pulling sprocket off the shaft. When replacing new sprocket be sure the set screw is in line with the flat on the shaft.

FEED SPROCKET

The feed sprocket is replaced by following the same procedure as described above for the removal of the sound sprocket.

HOLDBACK SPROCKET

The holdback sprocket is replaced by removing the two adjustment nuts, spring retainer, tension spring, the extension screw, friction washer and finally the sprocket. When inserting new holdback sprocket, place it on the shaft without removing the thrust bearing which is located at rear of shaft and reverse the above procedure.

TAKE-UP CLUTCH FRICTION PLUNGERS

To replace the take-up clutch friction plungers, remove the oil screw located at end of take-up assembly, Plate V-67, and loosen the two set screws as shown in D in Plate V-67, and pull the center disc off its shaft. It may require the force of a pair of pliers to do this. It is recommended that you wrap the assembly in a cloth so that the plungers will not spring out and do any damage when the disc is removed. In replacing the plungers you may find it necessary to make a clamp similar to a piston ring circular clamp in order to facilitate the reassembling of the unit.

UPPER FILM TENSION SHOE

To remove the upper film tension shoe, loosen the

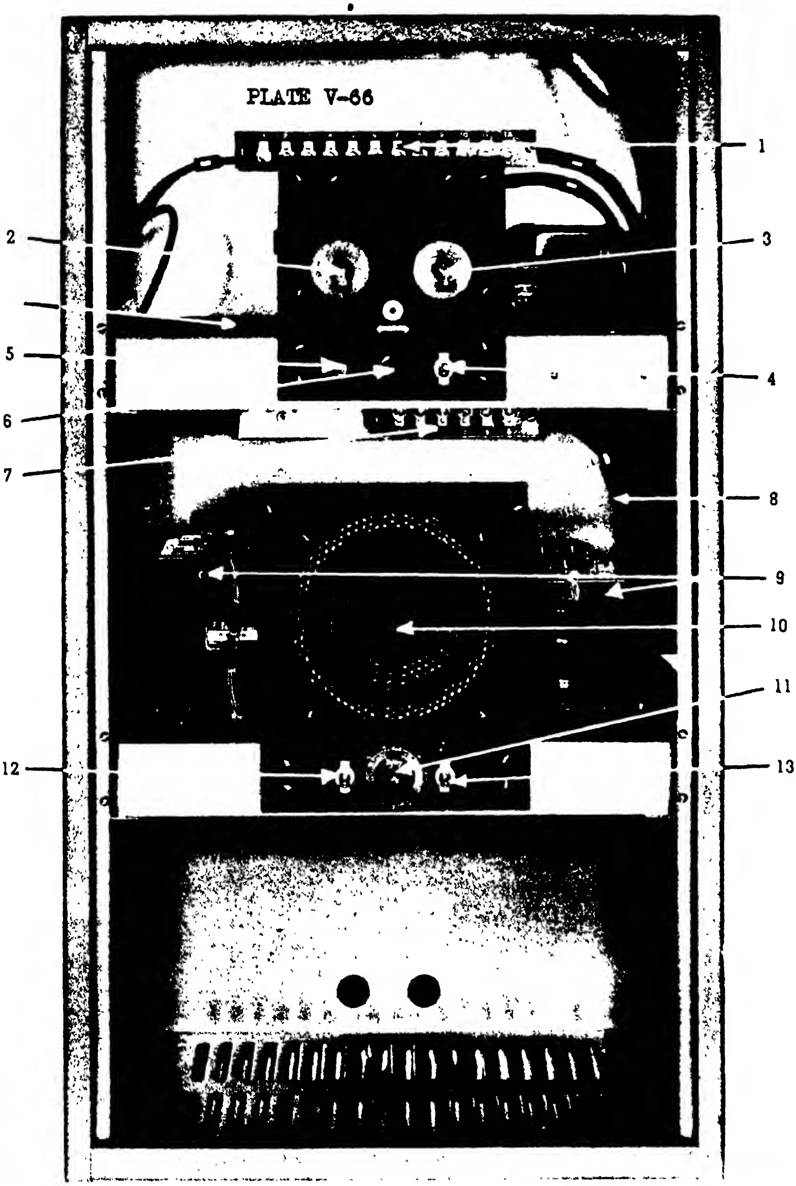


PLATE V-66
1
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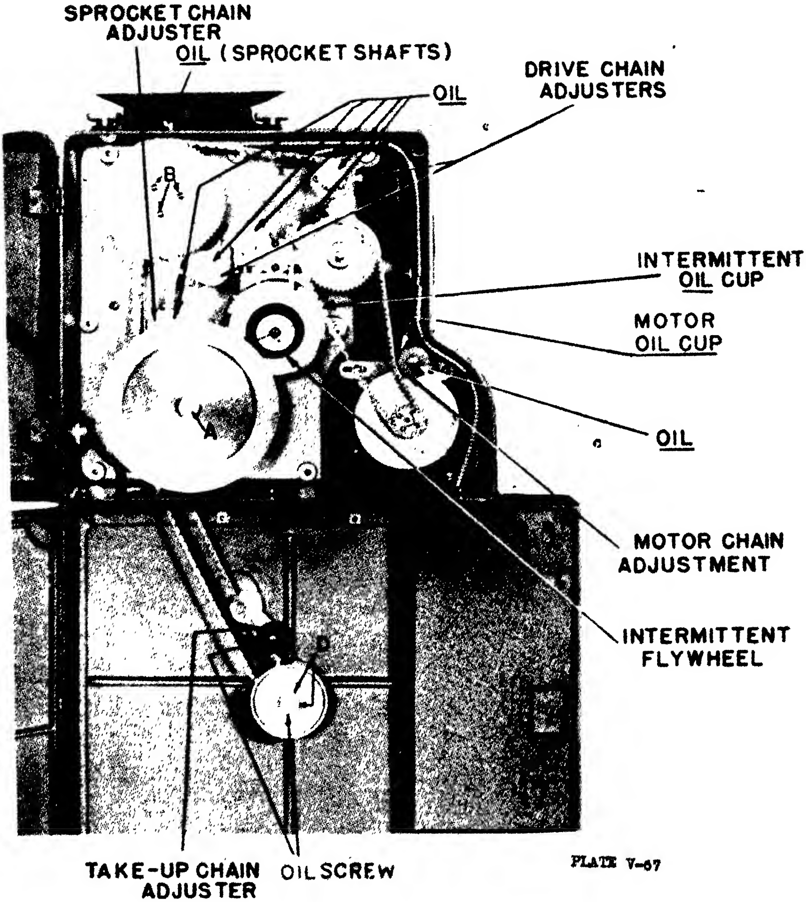

SPROCKET CHAIN ADJUSTER
OIL (SPROCKET SHAFTS)
OIL
DRIVE CHAIN ADJUSTERS
INTERMITTENT OIL CUP
MOTOR OIL CUP
OIL
MOTOR CHAIN ADJUSTMENT
INTERMITTENT FLYWHEEL
TAKE-UP CHAIN ADJUSTER
OIL SCREW

PLATE V-67

two screws located on the end of the studs to which the springs are mounted. Then, slide the washers and springs off these studs. Observe the position of these washers so as to place them in the same location when mounting new shoe. Reverse above procedure to install new shoe.

APERTURE FILM TENSION SHOE

To remove the aperture film tension shoe, the pressure plate assembly must be withdrawn from the mounting block. This is done by unscrewing the four round head screws, two of which are located above the aperture film tension shoe and two below. Then remove the knurled tension shoe adjustment bracket and the pivot screw.

Finally, unscrew the two filister head screws at both sides of aperture opening, thus releasing the aperture film tension shoe. To insert new shoe, reverse the above procedure.

TROUBLES—SERVICING

A periodic check-up of the tubes in the amplifier system with a normal tube tester should be made at intervals of every 30 to 60 days, depending upon the usage given the amplifier. Deteriorated or noisy tubes should be replaced.

Not all tube testers will indicate a "gassy" tube condition which if present, might cause excessive current drain and result in sound distortion. Therefore, cathode or bias voltage readings should be made periodically on all tubes.

DIRT IN AMPLIFIER

Excessive dust, dirt or carbon from the arc lamps should not be allowed to accumulate in the amplifier, as these foreign substances combined with moisture or grease, adhering to switch contacts, socket prongs, etc., can create poor tube socket contact, leakage in wiring or between terminals, which naturally would result in extremely disturbing noises in the loud speakers.

All switches, volume controls, socket prongs, etc.,

should therefore be kept scrupulously clean. Carbon tetrachloride is commonly used for this purpose.

To guard against overabundance of moisture harming the amplifier, especially when this unit is to be idle for weeks at a time, we recommend the amplifier be turned on at frequent intervals and the tubes left burning for at least half an hour.

LOSS OF SOUND IN SOUND SYSTEM

If sound should be lost in the system, make these preliminary tests:

Check to see if Volume Control is ON. Determine if power is being supplied to the system and if fuses are good. Note if speaker switches are ON and if monitor volume control is ON or partly ON. Be sure Exciter Lamp is ON. Check to see if exciter lamp switches (manual and sound changeover) are in proper operating position.

If after making all of these preliminary tests and no sound is as yet reproduced from the loud speakers, further probing within the amplifier is necessary.

CHECKING AMPLIFIER FOR TROUBLE

Move the 6F6 driver tube up and down in socket making and breaking contact. If a "plop" is heard in the speaker system, amplifier and speaker are okay from there out. If no sound is heard in speaker, check connections on speaker system, rectifier tubes, output tubes, plate voltage, etc.

If sound is okay from driver stage, move back, stage by stage, until a point is found where no sound is heard when tube is moved in or out of the socket or by touching top grid of tube. This is an ideal, speedy method to use to find bad tubes.

Do not attempt to locate more serious trouble until it has definitely been determined that all tubes are functioning properly and that none are shorted.

If tubes are okay and no sound is as yet reproduced, then check for cathode or bias voltage on each stage. If no cathode voltage is obtained, probe for the following trouble:

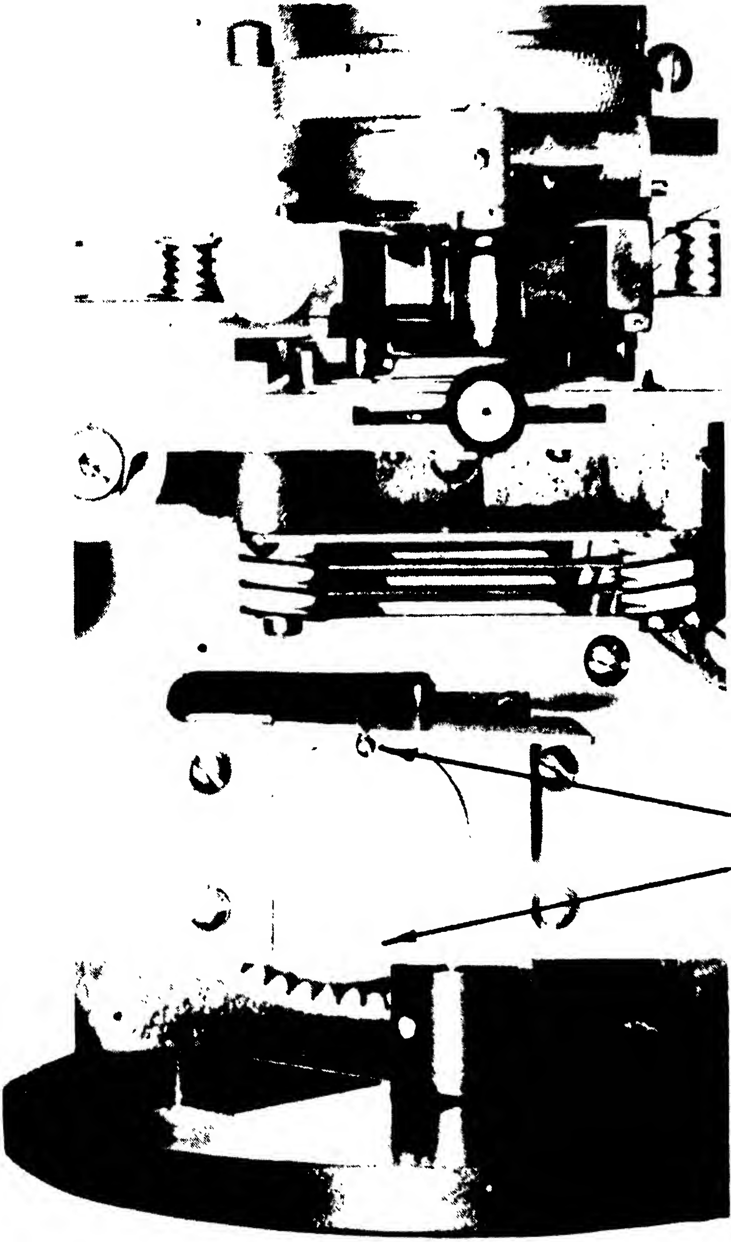


PLATE V-68

Substitute new rectifier or other interstage tube where cathode voltage reads zero. Determine if plate voltage is open or shorted. Determine if By-pass condenser is shorted. See if screen supply is open or shorted. See if screen By-pass condenser is shorted. Determine condition of cathode resistor.

If no plate voltage is obtained at any point after rectifier tube is found to be okay, the trouble may be caused by:—

Shorted condenser in main amplifier. Shorted condenser in monitor amplifier. Shorted condenser in either pre-amplifier. Short in wiring or line. Open or shorted power transformer winding.

No Photo-Electric Cell voltage may be caused by:—

Short in Photo-Electric Cell wiring. Shorted condenser. Open resistor. Shorted cell or cell socket.

POOR QUALITY OF SOUND

This type of trouble may be caused by any or all of the following:

Dirt, dust, grease or oil accumulation on slit lens. Remedy is to keep lens scrupulously clean at all times.

Improper alignment of sound track over sound drum.

Tension on holdback sprocket of projector too loose, causing slack in the film as it passes over sound drum.

Exciter voltage too low or exciter lamp out of alignment.

Defective photo-electric cell.

Weak or partially shorted tube in sound system.

Low or no field supply voltage on speaker field (where this type is supplied). Check field supply tubes and filter condensers and line to speaker fields.

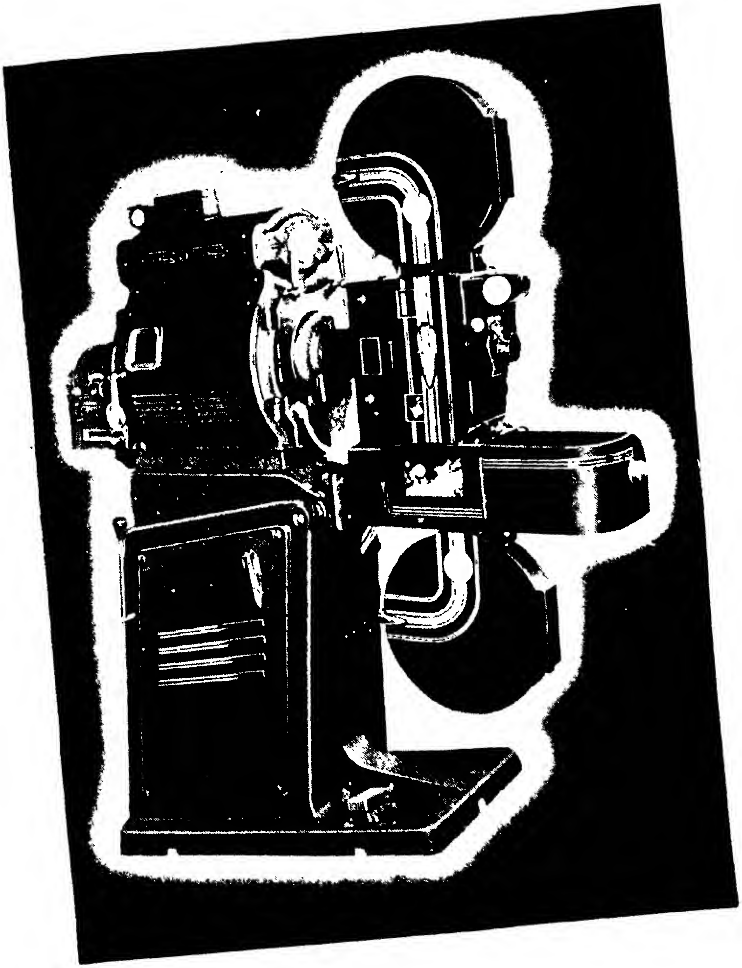
SERVICING EXCITER SUPPLY RECTIFIER

If the exciter lamp does not light, check:

Exciter lamp manual and sound changeover switches. Determine if exciter lamp itself is okay. Connections in exciter lamp socket. Line voltage to exciter supply. Check fuse in exciter supply. Check condensers for shorts.

Determine if proper contact is made between elements in selenium rectifier.

To remedy this situation, disassemble rectifier element, shorten insulating spacer. Clean plates, then reassemble with plates pressed together tightly, keeping all plates insulated from mounting bolt.



BRENKERT PROJECTOR

This new projector is a product of the long-established Brenkert Light Projection Company of Detroit, Mich., who will be remembered by the craft as manufacturers of the widely used Brenkert Scenic Effect Projectors, Brenkert Spotlighting Lamps and Automatic Arc Lamps for motion picture work.

The projector and all its working parts are completely enclosed and as will be seen by the photograph the projector is of modern streamlined proportions.

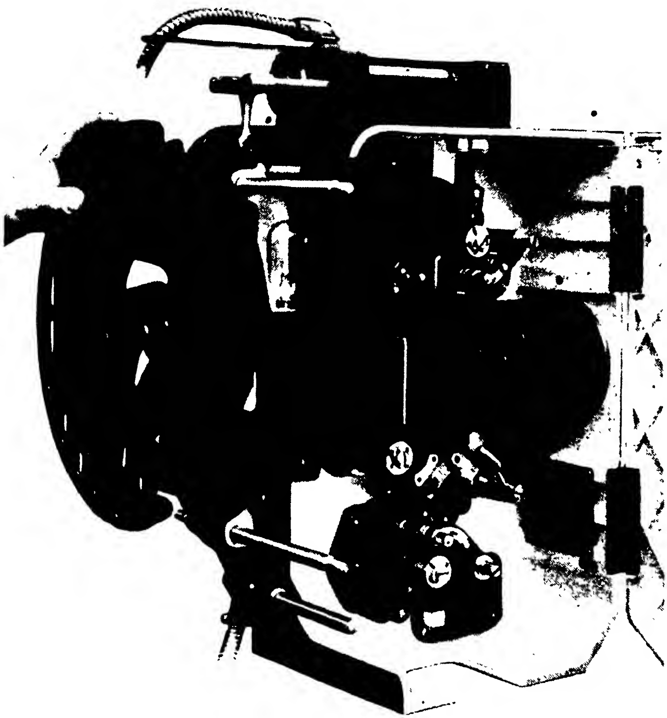
DOUBLE REAR SHUTTER

The double rear shutter blades travel in opposite directions within 3/8" of the same plane. This construction results in approximately 20% more light being passed to the screen than is possible with any other shutter design. The double shutter increases picture definition and reduces shutter flicker to the minimum. Both shutters being placed between the light source and the film results in a minimum of heat on all parts of the aperture and the film. Both shutters can be quickly removed, and as quickly replaced, without disturbing the timing.

The shutter blades are not used for pumping air from the aperture plate. As a result—air is not either pumped into or sucked out of the lamphouse. The arc is therefore not disturbed by air drafts from the projector and it is unnecessary to place any protective glass in the light beam with its consequent loss of illumination. This is very important in maintaining correct operation of arc lamps and consequent excellent screen results.

THE INTERMITTENT MOVEMENT

Micrometer adjustment is provided for the star and cam relation, by the Brenkert method of sprocket mounting, the sprocket is removed for replacement by simple loosening of



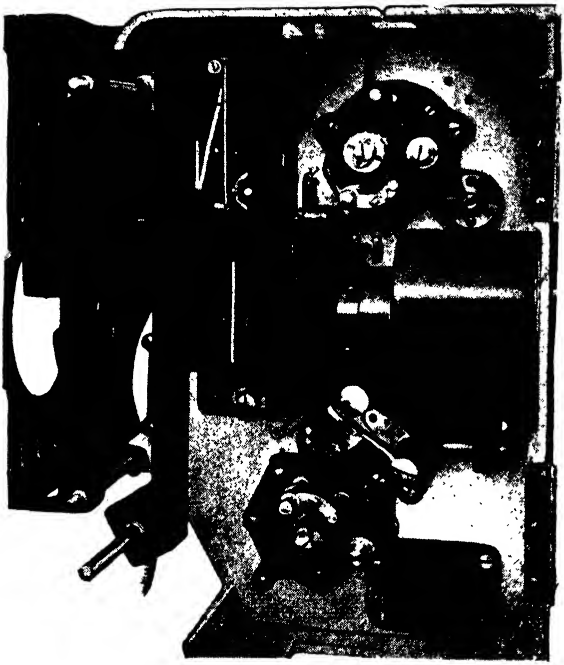
one screw, and without the necessity of removing the intermittent from the projector head, thus the work can be easily and quickly completed.

The star and cam are of generous size presenting three to four times the bearing surface of other make intermittents.

LENS MOUNT—FRAMING KNOBS—CHANGE-OVER

The lens mount accommodates preset type extension tubes

as supplied by prominent lens manufacturers; or will accommodate those types lenses that must be held on the small diameter. Releasing a lever on the front of the mount releases the lens for cleaning. Long wide bearings assure accurate replacement of the lens. Rugged construction and close fitting of all parts maintains accurate focus. The entire mount is quickly removable as a unit.



Framing knobs are located on both sides of the projector. One revolution of the knob frames a full picture.

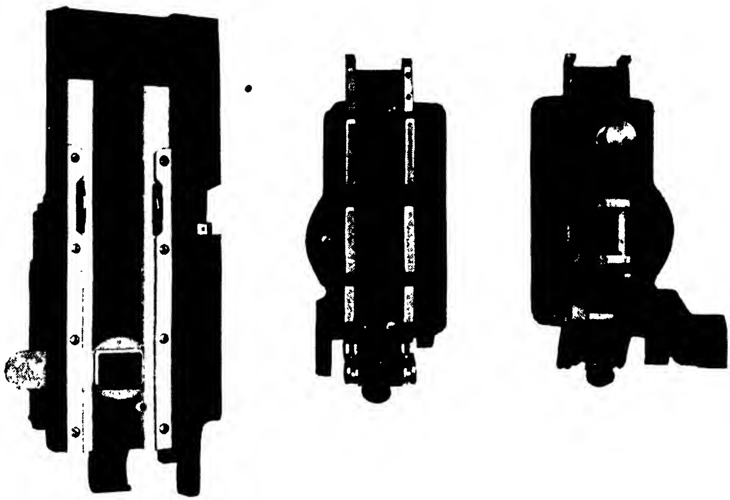
The Changeover Magnet is large and rugged for heavy duty, and attaches to the Projector without machining. It is noiseless in operation and quickly removable as a unit.

THE FILM TRAP AND GATE

The aperture casting is of high precision manufacture; carefully heat-treated, and will not warp under continuous heat of high-powered arc lamps. The aperture plate can be instantly removed for cleaning while picture is being

projected. Guide strips at both sides of the films, in combination with guide rollers at the top, reduce film side sway to a minimum.

The gate is ruggedly constructed with adjustable tension on all three pressure pads, and also on the tension shoe for the intermittent sprocket. The gate is quickly removable as a unit for cleaning by means of one large thumb screw.



DUST-PROOF MECHANISM COVER

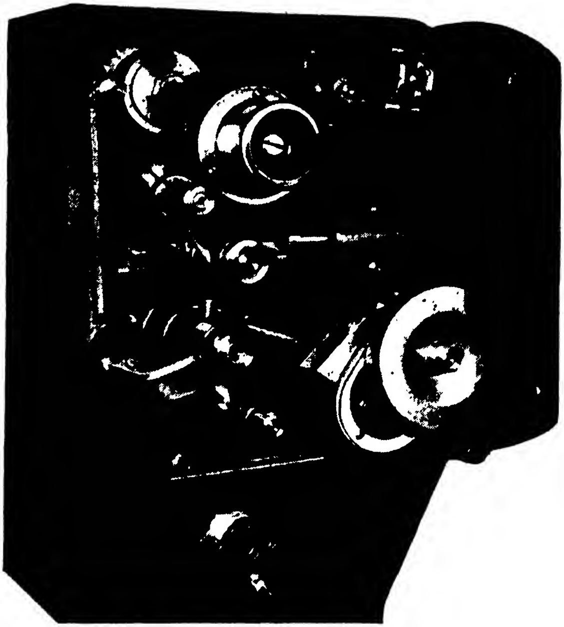
A quickly removable cover with oilproof Neonprene gasket attached prevents any dust from settling on the gears or in the bearings of the entire mechanism. This safety factor greatly aids in maintaining the high accuracy of the moving parts. A shatterproof glass window permits viewing the operation of the mechanism without removing any door or cover.

THE MECHANICAL FUSE

A steel key located on the outside gear face at the bottom of the gear train safeguards the entire mechanism in case

film breakage results in film pile-up on any of the sprockets. In such happening this key will shear, stopping the mechanism before any part of the projector is damaged. The key is easily replaced by removal of one screw in only a few seconds time. The show goes on with a minimum of interruption and no damage.

All moving parts are automatically and continuously lubricated.



A geared pump inside the housing delivers a continnous flow of oil through a large pipe from the reservoir at the base of the main frame to the rotary lubricator which throws the oil to every bearing and over all the gears. All shafts are spiral grooved the entire length of the bearings, forcing the oil through the entire length of the bearings several times per minute and draining back to the reservoir. This perfect lubrication is positive to all bearings, on any angle of projection; has no small pipe lines to clog; prevents bind-up; maintains the close accuracy that is built

into all parts, and completely relieves the operator from hand oiling.

All gears are 3/8" wide face of the helical type, giving a full 3/8" wide bearing from one gear tooth to the other, reducing wear and backlash to the minimum. There are no angular driven spiral gears, with their necessarily loose-fitting and rapid wear, in any part of the projector.

There are six helical gears between the intermittent driven gear and the shutter shaft gears. These absorb the intermittent impulses preventing these impulses from reaching the shutter shafts. The result is no picture streaking at any time from oscillating shutters.

The governor of the fire shutter is of the loaded type, operating in a horizontal position at all times so that its operating accuracy is maintained at any projection angle.

All gears and shafts are scientifically heat-treated to best perform the duty of their particular function. Workmanship and accuracy are of high precision standard. All bearing surfaces throughout the projector are large diameter and of generous length to assure rigidity and long wear.

No oiling is necessary on any parts of the film side. The three sprocket shafts are automatically lubricated from the mechanism side; no oil-retaining gaskets are used on any revolving shafts, therefore there is no possibility of oil leaks developing. A unique design of oil retainer—operating on the principal of centrifugal force and revolving with each of these shafts prevents any oil from reaching the film side of the projector. Therefore oil does not deposit on the projector lens or the film regardless of the age of the projector.

The lens mount is completely enclosed, preventing dust from settling on the lens; has microscopic focusing and pre-set lens feature whereby the lens can be removed and accurately replaced to its former position.

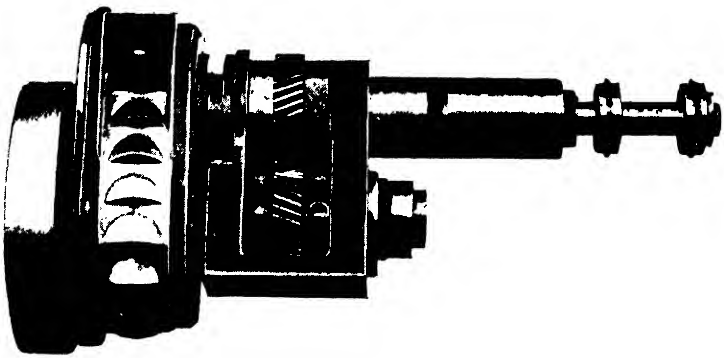
The aperture is automatically cooled by a quiet-operating Sirocco type fan located in the housing and driven by the gear train. Air is drawn from below the aperture opening, past the aperture cooling fins and exhausted at the top of the projector. No air is either drawn from or blown into the lamphouse, permitting the arc to burn steadily and feed accurately without arc disturbance; a very important factor

with mirror type arc lamps.

Micrometer timing of the shutters while the projector is running is accomplished by turning the shaft directly above the lens mount. This adjustment also compensates for any slight wear in the gear train over a period of years of operation.

PROJECTOR BASE

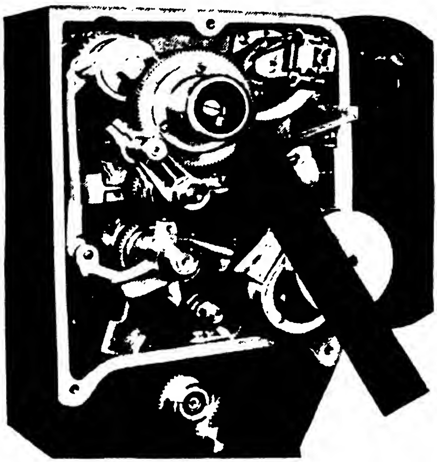
The main frame is a one-piece iron casting of sufficient floor area to maintain rigidity with even the largest of present-day sound heads in conjunction with the Brenkert Projector. The swivel point is located close to the projector and sound head mechanism for rigidity. Locking screws on both sides of the main frame hold the entire equipment rigidly.



The micrometer acting tilting mechanism operates for projection angles of 36° downward to 10° upward. Three compartments are provided for carbons and tools. The carriage for the lamphouse is adjustable vertically and laterally for close optical alignment of any standard make projection lamp with the projector mechanism.

All electrical connections and switches are inside the main frame, including 100 amperes switch, with control

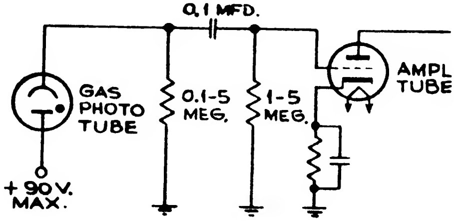
levers on both sides of base; two toggle switches for controlling the sound head drive motor from both sides of the base, and one toggle switch for controlling the relay switch where rectifiers are used. An emergency light socket is



Rotary lubricator on gear side of projector.
Automatically lubricates all moving parts.

mounted on the front panel, and changeover switch mounting is provided on the bottom.

Full opening panels on both sides give complete access to the interior. Four leveling screws and pads are provided.



-Typical Phototube Circuit-
Sound Reproduction

CHANGING INTERMITTENT SPROCKET

The sprocket can be changed on this movement very quickly by the projectionist. It is extremely simple. Just remove the end screw on sprocket shaft, also relieve the film stripper to enable the sprocket to be pulled, then sprocket can be removed from the shaft. There is no disturbing of gears, sound unit, or any other major work to perform. Shutter timing remains perfect. All that is required to do this work is a medium screwdriver. In replacing sprocket, do not set up hard on the holding screw. Finger and thumb pressure is all that is necessary as the sprocket is positive locking. The duty of the screw is to take up light end thrust. If sprocket is to be reversed after removal, it will be necessary to remove the two small taper pins which hold locking flange to sprocket, also the two small screws which locate this flange. The flange can now be placed upon the other end of sprocket and the pins can be reset and the screws tightened. The pin holes have been reamed and the screw holes have been tapped to facilitate this procedure.

REMOVING INTERMITTENT FROM MECHANISM

The entire intermittent assembly can be removed and replace while a thousand foot reel is being run on the opposite projector. The procedure is to remove gear side main cover and gasket. It will be noted that there is a clamping device which is mounted on center frame by means of a shoulder screw. This clamp is made of spring steel and locates in the outer quill adjusting slot on the intermittent proper. To loosen clamp, unlock 10/32 lock nut on adjusting screw. Back screw out until clamp is loose. Raise clamp fork up sufficient to allow locking slot in movement to clear, then remove the complete intermittent assembly. To replace, reverse procedure. The intermittent must be properly aligned with locking key in center frame bearing, as well as guide rod on framing lever when replacing. Do not set up too hard on 10/32 locking screw when replacing clamping device. One thread tight is sufficient.

If intermittent movement is removed from the projector for any reason, it will be necessary to retime the opposing cut-off shutters.

REMOVING LOWER SPROCKET

The sprocket can be removed and replaced (just as on the intermittent) without removing any castings or other parts. Be sure to relieve the film stripper when removing. This prevents damage to the sprocket.

REMOVING SPROCKET UNIT

The unit can be removed in its entirety by removing the three fillster head screws from the main casting flange. A new oil seal gasket should be used in replacing; otherwise, leakage might result.

LUBRICATION

Fully automatic. The lubricant is fed to the driving gear and shaft of this part from the gear side by the rotary lubricator. The film pad rollers have graphite impregnated bearings.

ADJUSTING LOWER SPROCKET ASSEMBLY

The adjustment of the pad rollers is accomplished by a stop screw and lock nut, which determines the proper distance from roller to sprocket. This is set at factory, but the allowable distance should not be more than .015". To remove pad rollers, loosen the small screw on arm. Remove stud lock spring and pull out roller studs. These rollers should be cleaned at intervals.

REMOVING UPPER SPROCKET ASSEMBLY

If it is ever necessary to remove the unit in its entirety, the gear side main cover must be removed and the large formica gear that carries the rotary lubricator must be removed (just loosen end screw in shaft) then pull off gear and lubricator.

A small oil tube coming from the pump is fastened by means of a clamp on the top of the casting.

ADJUSTING SHUTTER SHAFT ASSEMBLY

On the operating or film side of the projector properly located in the front upper center housing is an adjusting shaft with a screw slot. This is the only adjustment, and is a micrometer compensator for any slight "travel ghost" that might be incurred. This adjustment should be made while picture is being projected.

TIMING SHUTTERS

The timing of the opposing blades of the light cut-off shutter is accomplished as follows:

Looking from the rear of the projector with the right hand side of the shutter housing removed, it will be noted that the two blades are mounted on flanged hubs of different diameters. The inner blade is mounted on the larger hub, and the outer on the smaller. In the face of these two hubs will be noted two 10 x 24 fillister head machine screws which tighten the hub flange on to the blade proper.

The necessary operation of timing the shutter is to determine the movement of the intermittent by hand in such a way that the movement sprocket will just start its pull down. Now, loosen the 10 x 24 screws mentioned by one turn each, and it will be found that the blades can be moved independently on the hub without disturbing the intermittent setting or moving the mechanism. Looking from the rear of the projector, the inner blade, or the one with the large hub, moves in a counter-clockwise direction and can be moved up in that direction until it divides the aperture plate in half with the intermittent sprocket in a position of just starting to register. Take the outer blade, or the one with the small hub, and move it in a clockwise direction until the two blades meet directly in front of the center of the aperture opening. Now, tighten the two 10 x 24 screws in the large hub as well as the small hub. This again locks the blades to the driving shaft of the respective shutters.

To check this procedure, turn mechanism by hand

several times to determine whether the edge of blades are meeting exactly in the center of the aperture as the intermittent sprocket starts its pulling down function. If this checks O. K., then shutters are in correct time for projection. However, if a slight "ghost" should be noted, the "ghost" can be removed by a slight turn to the right if the "Travel Ghost" is up. If down, a slight turn to the left will remedy this. Be sure to have adjusting stud on operating side of the projector divided equally before timing procedure is started. This will allow leeway for taking out any slight "Travel Ghost" as before stated. Seven turns with a screwdriver on the adjusting stud will place it in the center of adjusting position from either stop. The shutters are timed at the factory when shipped to the theater, and retiming will only be necessary when the intrmittent movement is removed and replaced.

NOTE: Do not disturb the set screws which hold the hubs to the driving shaft. The shutters cannot be timed in this way due to fixed counterseats in each shaft. As has been noted, the shutters are held with a gripping action between the flange of their respective hubs. The timing can be accomplished by removing only the right section of shutter housing and quarter panel. The job can be accomplished with a medium sized 6" screwdriver, which is the only tool necessary, without backing up the projection arc lamp or disturbing any other fixed set-up.

REMOVING LUBRICATING PUMP UNIT

The unit can be removed by loosening the four fillister head screws in unit casting on operating side. The oil gauge must be turned slightly to get at one screw. The oil feed tube must be unclamped from casting and lifted from pump. Unit then can be removed.

There should never be any reason to remove this unit as it is so designed that wear is very improbable, and then only after a long period of time.

LENS MOUNT ASSEMBLY

Always keep the pre-focus collar tight after final setting. In this way, any projectionist on any shift, can clean the lenses without losing definition of picture.

The micrometer focusing knob assembly is designed to give an accurate close adjustment to the lens holder. It is smooth and positive in operation.

Always keep lens so mounted that there is ample focusing distance to adjust in or out of focus.

FILM GATE

The adjustable tension on the film gate is accomplished by an adjusting knob on the rear of the gate housing. Turning to the left decreases the tension, while turning to the right increases the tension. This controls tension on all three pairs of pressure pads in the gate. The intermittent film pressure pad has individual adjustments of the same type. Film should be run at the lightest tension possible. These shoes will be set accurate at the factory, but can be re-adjusted any time by the projectionist. After adjusting, the "jam nuts" shall be locked in both cases to prevent the adjustments from "creeping."

Do not run with unnecessarily excessive tension on the gate film pads or intermittent pressure pad. Premature wear of the film sprocket holes will result.

RCA REPRODUCING EQUIPMENT

In this chapter we will outline briefly some of the latest systems introduced by RCA Photophone.

PG-105 SYSTEM

The PG-105 system is intended for use in theaters with less than 500 seats. The amplifier used in this system is the Type MI-1223. It has a rated power output of 5 watts. The amplifier has a built-in Monitor Speaker control.

A number of changes have been made since the system was first introduced. One of these changes is that a Throat Insert has been included for the High Frequency Horn. This insert increases the loading on the cone of the high frequency speaker, thus improving the high frequency response. The length of one low capacity cable has been increased to allow a heater installation. This is most desirable in some of the newer projection rooms where the tendency is to increase the spacing between the projectors.

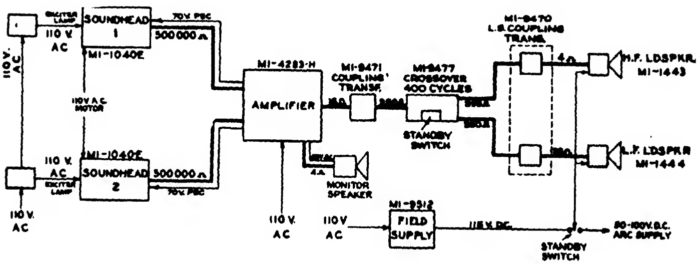
The output stage of the MI-1223 amplifier uses two RCA-42 tubes connected as triodes, operating in Class A. Overall volume control is obtained at the front of the amplifier rack. The amplifier is intended for wall mounting.

PG-138 SYSTEM

This system is intended for use in theaters with a seating capacity of less than 800. The PG-138 Amplifier Cabinet mounts on the wall, the output stage of the amplifier contains two RCA-42 tubes connected as triodes operating in Class A. The rated power output is 8 watts. The volume control is mounted on the front of the amplifier cabinet.

The crossover network is located in the main amplifier cabinet. A standby switch is provided on the crossover network which connects the low frequency speaker mechanism directly to the amplifier output in the event of failure of the high frequency speaker mechanism or some component of the crossover network.

An exponential cellular high frequency baffle is provided which uses a single MI-1443 high frequency speaker mechanism. A large folded frequency baffle is driven by a single MI-1444 low frequency speaker mechanism.



PG-138 System Functional Diagram

PG-139 SYSTEM

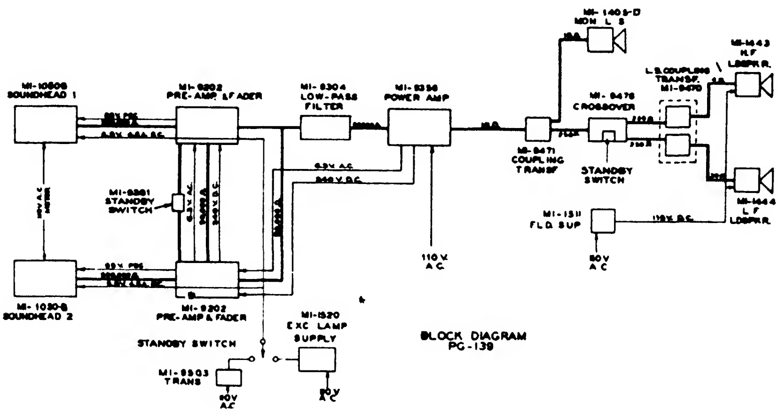
The PG-139 System is intended for theaters with a seating capacity not exceeding 1,200. The equipment includes two combination pre-amplifier and fader units which mount on the wall and are low capacity coupled to the soundhead. The output of the pre-amplifier units is fed into the power amplifier through a high impedance line. The soundhead used in this system is the type MI-1050.

The output stage of the power amplifier contains four RCA-1622 tubes connected in push-pull parallel operating in Class A. The rated power output is 18 watts. Volume control is obtained on the front wall of each pre-amplifier. The power amplifier has overall feed back.

The compensation of the pre-amplifier is set to give the recommended Academy response curve for the speakers

supplied. Provision is made in the pre-amplifier to alter this response slightly to compensate for auditorium acoustic conditions. The cross-over network is mounted in the amplifier cabinet with a stand-by switch to connect the amplifier output directly to the low frequency speaker. The same speaker installation that is used in the PG-138 system is used.

A D.C. exciter lamp supply unit is supplied with a stand-by switch which provides for A.C. operation in case of emergency. The "Off" lamp is pre-heated by means of a low voltage alternating current to prevent lag.



BLOCK DIAGRAM PG-139

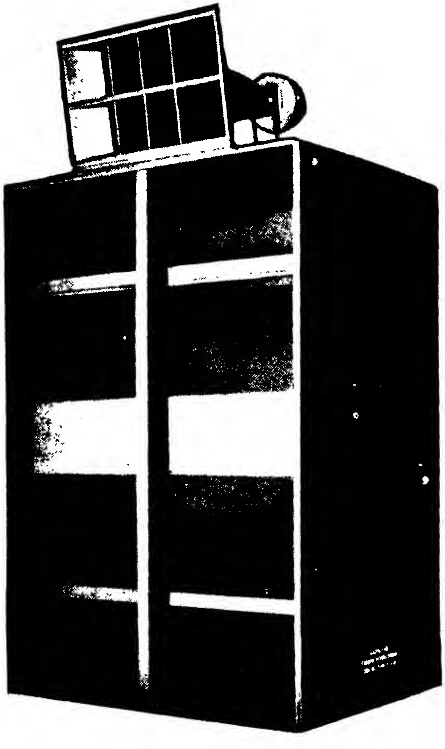
PG-140 SYSTEM

This system is intended for installation in theaters of 1,800 seats or less. The system employs the new MI-9050 soundhead. The equipment is all rack mounted. The PG-140 Rack contains the MI-9328 Voltage Amplifier, MI-9375 Monitor Amplifier, MI-9354 Power Amplifier, MI-9475 Crossover Network, MI-9510 Loudspeaker Field Supply and the MI-9502 Exciter Lamp Supply.

The soundhead energy feeds directly into the MI-9328 Voltage Amplifier, this unit has the following specifications —Input impedance of 250 or 500 ohms, Load impedance 250 or 500 ohms, a frequency response of plus or minus 1db. from 30 to 10,000 cycles, a gain of 55 db., a maximum

output level of plus 6 db., output noise level of minus 8 db., and a feedback of 18 db.

This amplifier uses two RCA-1620 tubes connected as pentodes. The output of this amplifier feeds into the MI-9303 compensator, where all compensation is done.



PG-134 Loudspeaker System

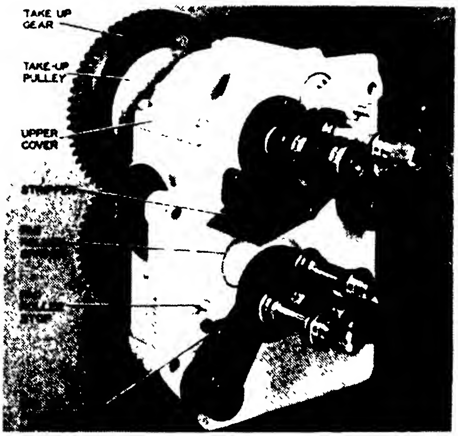
Adjustments may be made at the compensator panel to adjust the response best suited for each individual theater, and acoustic conditions.

The volume control is connected in this link circuit between the voltage and power amplifier. It is mounted physically on the front wall in one of the fader units. An extension rod makes the volume controllable from either projector position. The output of the compensator feeds

directly into the MI-9354 Power Amplifier. This amplifier uses four RCA-1922 tubes connected in push-pull parallel, operating Class A in the final stage. The amplifier has an input impedance of 250 or 500 ohms, a load impedance of 7.5, 15, 250 or 500 ohms, a frequency response of plus or minus 1 db., 30 to 10,000 cycles, a gain of 66 db., rated output of 25 watts. Inverse feedback is used on all stages of the amplifier as well as on both stages of the voltage amplifier.

One RCA-874 voltage regulator tube is incorporated to maintain constant voltage for the phototube supply which is taken from this amplifier.

The MI-9475 crossover network is mounted on the rack and contains a standby switch to connect the output of the amplifier directly to the low frequency speaker mechanism.



-*Front View of Gear Box*

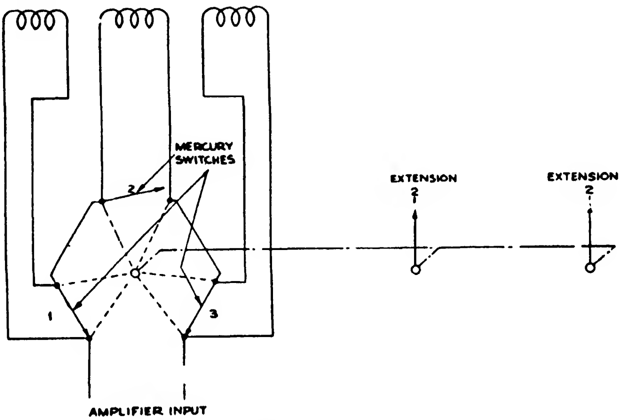
The MI-9375 Monitor Amplifier contains sufficient gain to operate directly from the soundhead output. A standby switch is provided so that in the case of a breakdown or failure of either the voltage or power amplifier, the show can be continued on the monitor amplifier.

A single RCA-1622 operating in Class A is used in the output. One RCA-991 is used as a voltage regulator on the

phototube polarizing voltage supply, which is obtained from this amplifier in standby position.

The MI-9510 Field Supply Unit furnishes 1.5 amperes at 120 V.D.C., which is sufficient power for six loudspeaker fields.

The MI-9502 Exciter Lamp Supply furnishes 9.0 amperes at a maximum of 12.0 volts D.C. for two exciter lamps operating continuously in parallel. A standby switch is provided which makes it possible to use A.C. on the exciter lamps in the event of failure of any part of the supply unit.



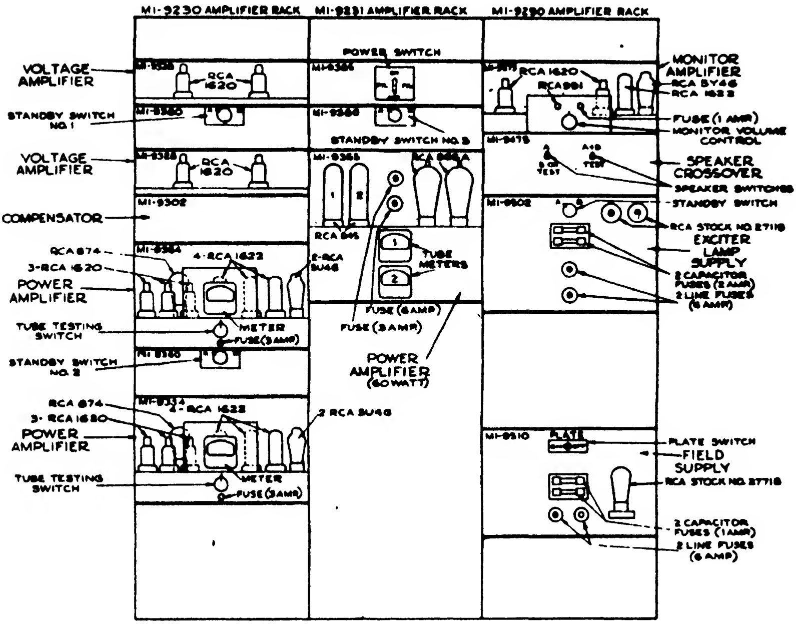
Schematic of input circuit.

A newly developed mercury contact switch is used in the fader for changing-over the sound. In the past, change-over switches and relays of all types have given more or less trouble due to dirty contacts caused by oxidation and arc dust. The contacts of the new switch are sealed in glass so they cannot oxidize or collect dust. In operation the outputs of the two soundheads are connected in series, the mercury fader switch shorts the output of the machine not in use.

The loudspeaker equipment consists of two MI-1443 high frequency speaker mechanisms on an exponential cellular horn, and two MI-1444 low frequency speaker units in a folded exponential low frequency baffle.

All amplifiers are hinge mounted so that they may

readily be swung out for inspection or servicing. The system is equipped with meters with selector switches, so the tubes may be tested while the system is in operation.



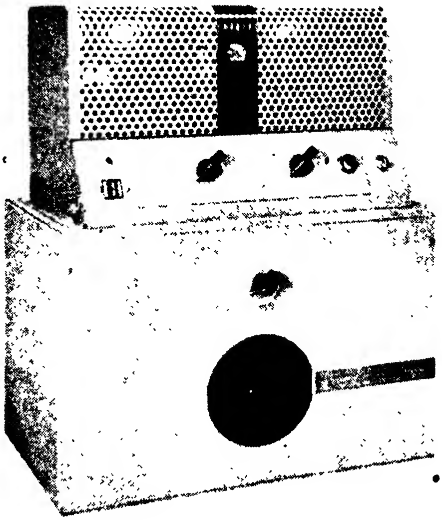
PG-142 System—Amplifier Racks

PG-141 SYSTEM

The PG-141 system is for theaters with 2,600 seats or less. The equipment is mounted on two racks. Rack number one contains the following: 2 MI-9328 Voltage Amplifiers, 2 MI-9354 Power Amplifiers, 1 MI-9302 Compensator, and 1 MI-9380 Standby Switch. Rack number two contains: 1 MI-9502 Exciter Lamp Supply Unit, 1 MI-9375 Monitor Amplifier, 1 MI-9475 Crossover Network and an MI-9510 Field Supply Unit.

The information given covering the amplifiers and power supply units for the PG-140 System applies to this system

too. The MI-9380 standby switch makes it possible to use either of the voltage amplifiers. The MI-9354 Power Amplifiers are paralleled so that if one fails the show may continue on the other. Since this equipment has two 25-watt amplifiers, it is rated at 50 watts.



PG-134 Amplifier Cabinet

The MI-9302 compensator supplied with the equipment allows slightly greater latitude of adjustment than that obtained with the MI-9303 compensator used in the PG-140.

The Fader and volume control system is identical with the one used in PG-140. An additional low frequency folded exponential baffle has been added to the equipment along with two additional MI-1444 speaker units and one MI-1459 extension baffle.

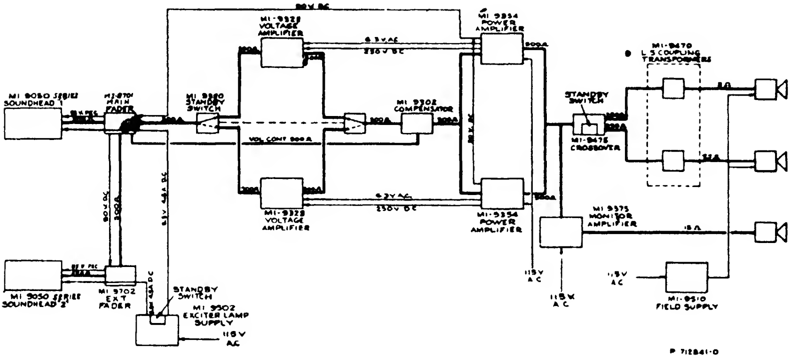
PG-142 SYSTEM

This system is for installation in theaters with a seating capacity of approximately 3,800. The complete equipment is mounted on three racks. Two MI-9328 Voltage Amplifiers are provided with 1 MI-9380 standby switch which

selects either amplifier.

The output of the selected voltage amplifier drives one of two MI-9354 25-watt power amplifiers. A standby switch is provided for selecting either one of the two 25-watt amplifiers.

The output of this 25-watt amplifier drives an MI--9355 60-watt power amplifier. This amplifier contains two RCA 845 tubes operating in Class A, in push-pull.



Block Diagram - PG-141

The characteristics of this 60-watt power amplifier are as follows: It has an impedance of 500 ohms, a load impedance of 15, 30 or 250 ohms, a rated output of 60 watts maximum power output of 140 watts, a gain of 15 db. and a frequency response of plus or minus 1 db. 30 to 10,000 cycles.

The MI-9380 standby switch disconnects the 60-watt amplifier from the circuit in case of trouble. Operation may continue on one of the 25-watt amplifiers. The Fader and volume control systems, as well as the exciter lamp supply, field supply and monitor amplifier, are identical to those already described for the PG-140. The speaker complement is the same as that used in the PG-141 system.

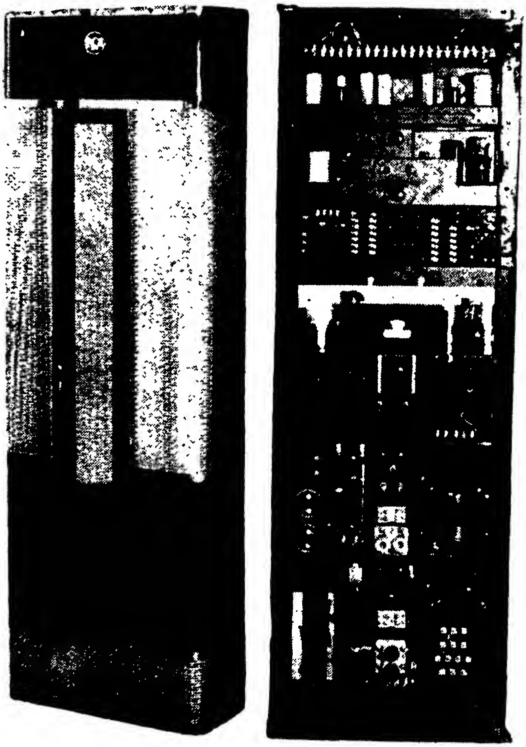
THE MI-9050 SOUNDHEAD

This 9050 soundhead is really the 1040 soundhead with certain improvements. A cover has been added over the

motor to give the soundhead long flowing lines. The window in the sound compartment is edge-lighted, giving the unit a very attractive appearance when in operation.

A plate has been added to protect the soundhead from oil damage.

The projector and take-up drive are all taken from the hold-back sprocket shaft, rather than from the constant speed sprocket shaft, as was the case in the MI-1040 soundhead. This construction removes all irregular loading from



PG-140 amplifier rack cover for showing arrangement of units from top to bottom.

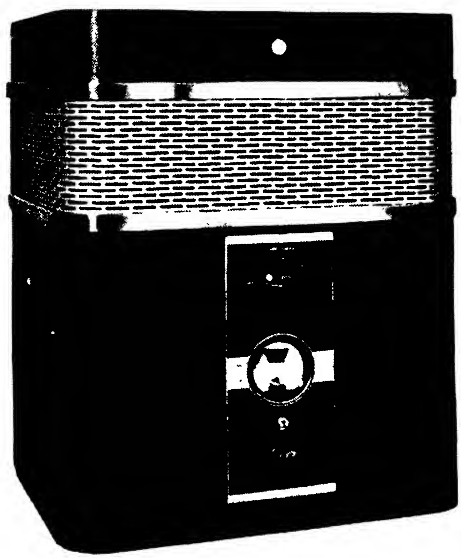
the constant speed sprocket shaft, which may affect the film loop and introduce "wows." The complete drive unit is removable for servicing.

The head is equipped with double exciter lamps with pre-focus bulbs. In the event that one bulb fails it is only necessary to reverse the lamp holder, bringing the spare lamp into use, to continue the show.

The complete phototube circuit including socket, leads and transformer is completely shielded.

The soundhead is equipped with a flywheel on the motor shaft to slow down the starting speed. A brake is provided for quick stopping should this be necessary.

The complete sound bracket containing the exciter lamp, optical system and drum shaft are easily removed for servicing.



There is an adjustable stop on the optical lens barrel focusing nut, which allows fine and quick adjustment of focus.

A shield is placed between the sprocket holes on the film and the phototube. This prevents the possibility of stray light being modulated by the sprocket holes and producing 96-cycle hum.

A separate switch is provided with each motor for front wall mounting, with "Bulls Eye" to indicate machine in operation.

RCA HIGH FIDELITY SOUND HEAD

The soundhead consists of a housing containing a removable exciter lamp socket with its mounting; an optical system for focusing the light upon the sound track of the film; a device for lateral control of the film; a sound take-off drum for carrying the film past the beam of light; a rotary stabilizer to insure an absolutely constant speed of the film around the sound take-off drum; a photocell and its transformer for translating the light variations, caused by the sound track of the film, into electrical pulsations; an exciter lamp switch for turning the exciter lamp current "on" and "off"; and an electric driving motor and motor switch.

The electric motor, either a-c. or d-c., depending upon the requirements of the installation, drives the soundhead, which in turn drives the projection head. The motor is directly geared to the soundhead.

The loop between the constant speed sprocket and the projector head lower sprocket should be such that, when their pad rollers are down and the lateral guide and pressure roller is latched in place, a firm pressure against the film just above the lateral guide and pressure roller will not quite bring the film into contact with the photocell condensing lens holder. This loop should be carefully and accurately set, because, if it is too large, the film will rub against the photocell condensing lens holder and become scratched, and if it is too small, sprocket-tooth "flutter" or "wows" may result.

The lateral guide and pressure roller must be closed and latched when the soundhead has been threaded. To do this, simply place a finger against the roller arm finger

pad and push to the right until the latch engages. This should be done with care as sound of poor quality will result if the roller is not latched.

There should be a four sprocket-hole loop between the constant speed and take-up sprockets to prevent any irregularity in the take-up reel being transmitted to the constant speed sprocket.

Aside from the pad rollers, there is but one oiling point on the film side of the soundhead. This oiling point is an oil cup located in the ball bearing of the lateral guide and pressure roller.

The pad roller should be oiled once each day. Only a small quantity of oil should be applied to the oil holes in the roller shafts at each application. It is recommended that they be oiled by dipping one end of a toothpick in soundhead oil and applying the oil that adheres to the toothpick to the oil holes.

Keep the large oil cup filled to within one-eighth inch of its top with soundhead oil. Put one drop of oil in each of the smaller oil cups twice each day.

About every three months the oil in the worm and gear compartment should be drained off, by removing the plate from the bottom of the compartment. The oil compartment should be thoroughly flushed out with kerosene and then refilled with fresh oil.

At least once a year the worm and worm gear should be examined to make sure they are in good condition.

The soundheads equipped for turntable drive contain a grease cup at the bearings of the gears which drive the turntable flexible drive shaft. This cup should be given one-half turn each day and when empty should be filled with any high quality cup grease.

Keep the soundhead mechanism well oiled and scrupulously clean; keep a tested spare exciter lamp pre-adjusted in the spare socket for each soundhead; and keep a tested spare photocell on hand for each soundhead, and you will be well repaid for your efforts by the continuously good performance of your equipment.

The optical system lenses should be cleaned periodically, preferably every day, with a soft clean piece of linen. The

exciter lamps and photocells should also be cleaned periodically to remove any dirt or oil which may have accumulated on them.

It is very important that the sound take-off drum be kept thoroughly clean. Foreign material such as dirt or film emulsion on the drum will cause poor quality, "flutter" or "wows."

Never use any metallic instrument such as a screwdriver, knife blade, etc., for cleaning purposes as any scratches produced on the sound drum may scratch the film, and scratched film produces poor sound.

Only dry, soft, lint-free cheese-cloth should be used to clean the lateral guide and pressure roller and the sound take-off drum. It may become necessary, at times, to moisten the cloth with Carbona in order to remove caked emulsion, grease or film wax from the roller or drum, but the use of solvents should be avoided as far as possible.

EXCITER LAMP ASSEMBLY

The exciter lamp socket is mounted in a bracket, which is guided into its proper place in the soundhead by long pins, and held in place by friction so that the lamp and socket assembly can be removed and replaced quickly without affecting its adjustment.

A spare socket assembly is supplied with each soundhead, and a spare exciter lamp should be set up in the extra socket, adjusted and placed conveniently aside for emergency use. The exciter lamp used is rated at 10 volts, 5 amperes.

The exciter lamp switch is mounted on the end of the soundhead casing, below and to the rear of the exciter lamp socket.

OPTICAL SYSTEM

The purpose of the optical system is to focus the light from the exciter lamp upon the film emulsion. The changing amount of light arriving at the photocell produces pulsating electric currents in its circuits and these pulsations are subsequently amplified and reproduced as sound.

SOUND TAKE-OFF MECHANISM

The sound take-off drum is set in motion by the friction of the smooth outside surface of the drum. A special damping wheel (rotary stabilizer) is attached to the drum shaft and the whole unit operates, independent of the soundhead gears, to prevent any variations in the speed of the film moving past the optical system light beam. This arrangement insures the absolutely constant film speed which is essential to high fidelity sound reproduction.

It is important that the sound take-off drum be kept thoroughly clean. Foreign material such as dirt, film emulsifier or oil on the drum or the lateral guide and pressure roller will cause poor quality, sprocket-hole or frame line noise, "flutter" or "wows."

PHOTOCELL AND ASSOCIATED PARTS

The light beam from the exciter lamp, after passing through the sound track of the film is collected by means of a condensing lens and deflected upward through an aperture in the cover of the photocell housing and against the photocell. The lens solder is attached to the photocell bracket.

The photocell transformer is located in a compartment in the rear of the soundhead casting.

The cover of the photocell housing may be removed by turning it counter-clockwise and pulling it straight outward.

DRIVING MOTOR

In AC installations either a splitphase induction motor or a three-phase synchronous motor is used with direct gear drive to operate the entire soundhead and projector mechanism. The speed of the induction motor, while not synchronous, is constant and depends upon the frequency of the power supply.

These motors are started and stopped by a tumbler switch mounted on the motor frame.

In all DC installations a standard, shunt-wound, direct current motor fitted with a speed regulating device is used. The DC motor is started and stopped by means of a switch mounted in a resistor box fastened to the motor frame.

The speed of the AC operated soundheads is determined by the frequency of the power supply line, the rating of the motors and other predeterminable factors. Since, in any AC installation, these factors are fixed, no speed adjusting device is necessary or desirable, the constant speed characteristics of the AC motors being sufficiently pronounced to overcome slight tendencies toward speed fluctuation.

The speed of DC motors depends upon a number of variable factors and the motors themselves do not have the same tendency toward constant speed operation as in the case of the AC motors. For this reason an adjustable speed-regulating device is incorporated in the design of the DC soundhead motors. The speed to which the motor is regulated may be changed by means of the speed regulating dial on the end of the motor housing.

A knob on the end of the AC motor shaft permits the projector and soundhead mechanisms to be slowly operated by hand when necessary. In the case of the DC motors, the speed regulating device occupies the position of the knob on the AC machines. A handwheel is therefore mounted on the motor shaft between the motor and the soundhead. An opening in the motor housing gives access to the handwheel.

OPTICAL SYSTEM

The optical system is a very delicate piece of apparatus and its only adjustment (focusing) should never be changed by the projectionist. If this focus is changed, the quality will be very poor; the higher frequencies will be lost, and all other frequencies will be distorted.

The accumulation of oil, dirt, film emulsion, etc., upon the lenses of the optical system, if permitted, will cause low volume of sound or no sound.

SOUND TAKE-OFF MECHANISM

It is very important that the sound take-off drum be kept thoroughly clean. Foreign material such as dirt or film emulsion on the drum will cause poor quality, "flutter" or "wows".

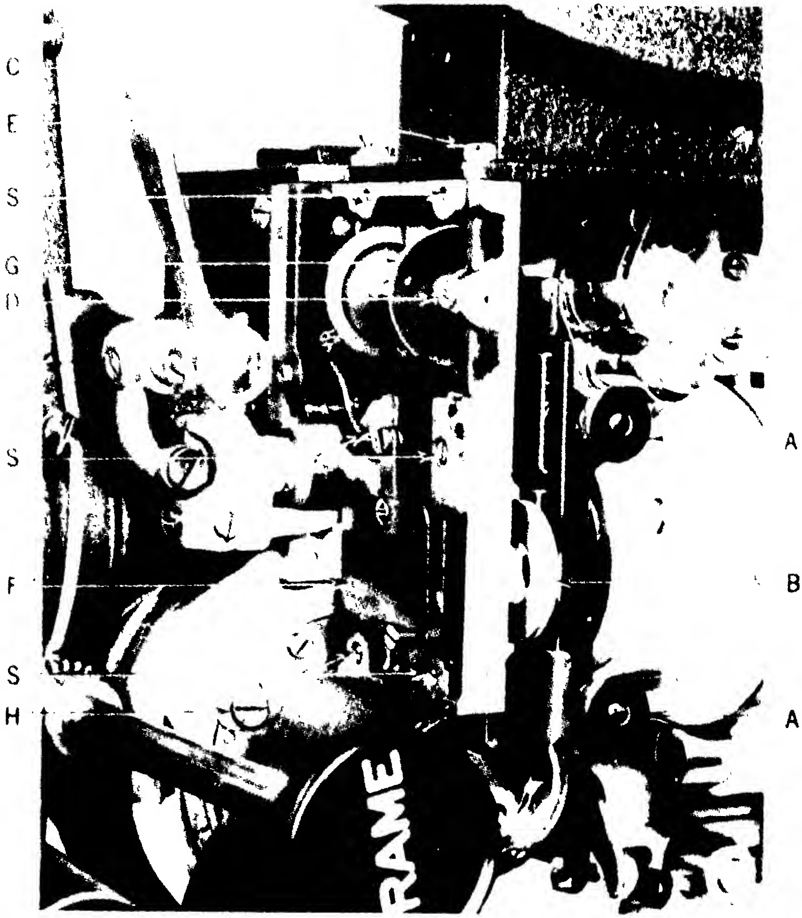
Never use any metallic instrument such as a screwdriver, knife blade, etc., for cleaning purposes as any scratches produced on the sound drum may scratch the film, and scratched film produces poor sound.

PHOTOCELL ASSEMBLY

The accumulation of foreign material on the photocell or photocell condensing lens may cause low volume. The photocell cover should always be in place while operating to prevent the occurance of hum or noise due to the admission to the photocell of exteraneous light of varing intensity.

DC DRIVING MOTOR

When the speed regulating dial of the DC motor is properly set, the crank shaft should make 90 revolutions per minute. For an accurate setting, the revolutions of the crank should be counted for three minutes.



A-Film Gate Retaining Thumb Screws
B-Aperture Plate Assembly
C-Film Gate Opening Lever in Open Position
D-Guide Roller Bearing Set Screw
E-Rear Fire Valve Retaining Screws
F-Fire Shutter
G-Guide Rollers
H-Intermittent Movement Clamp Screw & Clamp
S-Film Shoe Retaining Screws

THE SUPER SIMPLEX

THE new mechanism is supplied with the vertical sliding aperture plate in which are two standard apertures, one having the standard dimensions for straight silent film projection (0.906 × 0.6795 in.) and the other having standard dimensions for sound film projection (0.800 × 0.6795 in.), or the proportional aperture (0.800 × 0.607 in.) for the projection of sound film to give a screen picture of the same dimensions as obtained with the standard silent projection aperture. With the use of this latter aperture it is necessary to change to shorter focal length lenses and this can be readily and quickly done as will be explained later.

APERTURE PLATE

The aperture plate slides vertically behind the film tracks on the film trap. In its upper position it carries the standard silent film aperture. When slipped into the lower position it carries the standard sound film aperture or the standard proportional aperture, depending on which is ordered with the projector. When using the standard sound film aperture or the proportional aperture it is obvious that the lens mount with relation to the center of the aperture is off center, due to the masking of the sound track and, therefore, throws the picture to one side on the screen. On the front and top of the lens mount, outside of the mechanism is a lever which may be thrown laterally from left to right. In the right position the lens is accurately centered on the standard or proportional sound film aperture, and thrown over to the left position it will be centered for the standard silent or disc aperture. Stops are provided on this adjustment so that the length of its throw may be predetermined in order that the lens may also come

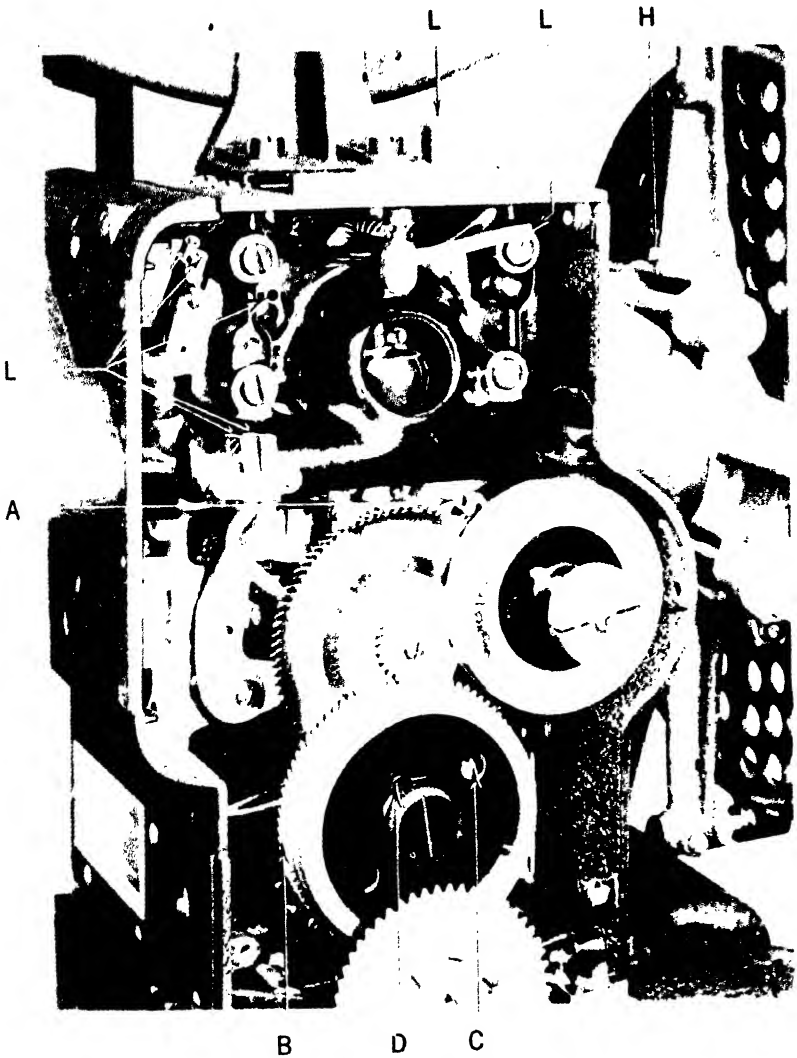
into the correct relation with the projection apertures and the projected picture; these stops fetch up against the stationary stop shaft. Ideal results are secured with this arrangement when using the proportional aperture because, when this aperture is used and a change made to the correct shorter focal length lens, a picture of the same proportions as that projected through the silent film aperture is projected to the screen, and by simply moving the lens centering lever to its correct position no further change is necessary on the stage, such as sliding in tabs or masks. Just within the glass door of the mechanism in the upper right-hand corner will be found a lens holder lock screw. This screw is attached to a clamp provided in order that the lens centering lever may, if desired, be locked in fixed position and also to apply a slight tension that eliminates vibration of the lens centering unit.

NEW REVOLVING SHUTTER

Several improvements in design have been incorporated in this shutter. Its extremely large diameter provides for increased screen illumination and, because of its position with relation to the lamphouse and aperture, it greatly reduces the heat at the aperture, operating as it does between the light source and the film. In addition to this, the shutter is so designed that it creates a partial vacuum in front of the aperture so that the cooling effect obtained during its operation reduces the heat at the aperture approximately seventy-five per cent over the older types of equipment. It will be appreciated that this is of utmost importance when projecting sound film because it reaches the sound projection aperture in an undistorted condition.

The entire shutter may be exposed by removing the front shutter guard. This is accomplished by simply removing three nuts and washers, and slipping the front shutter guard from its supporting studs.

The eye shield on the Super Simplex has been designed to protect the projectionist's eyes entirely from the bright rays from the spot at the aperture. This eye shield is an entirely



A-Intermittent Movement Oil Filling Tube
B-Main Drive Gear
C-Lower Sprocket Pinion Gear
D-Ratchet Spring & Main Drive Gear Retaining Screw
H-Framing Shaft Lubricating Tubes
L-Bearing Lubricating Tubes

enclosed device and the colored glass therein may be readily removed for cleaning. This eye shield together with the framing and threading lamp is attached by means of screws to the front section of the shutter guard. A slot is provided in the eye shield assembly just behind the aperture so that change-over devices using an aperture cut-off may be readily adapted.

A threading and framing lamp has been provided and is mounted below the eye shield assembly. This lamp directs a strong beam of light up behind the eye shield to the aperture and by this means it is possible for the projectionist to place the film in frame readily while threading the projector. A small switch is provided by means of which the lamp may be thrown on or off at will, and armored cable is supplied for connecting the framing lamp assembly to any convenient source of 110 volt supply.

Care of Simplex Mechanism

The speed control of the Simplex projector is of a design that has simplicity as its base. The action of the control is at all times positive, while in the matter of speed variations it is endowed with the utmost flexibility. Through its use the projectionist is enabled through a slight turn of the controlling handle to instantly attain a minimum or maximum of speed, without the slightest strain upon the mechanism or without imposing any sudden burden upon the motor.

The starting mechanism device, when thrown out, permits the motor control to run idle, but when thrown in by a slight opposite turn of the handle starts the mechanism into action at any required speed.

The principle of the control being to acquire any desired speed within a minimum of time, we note that the driving belt is passed in "L" shape formation over the driving pulley of the motor and across the main speed control pulley. Then the the belt is run over and under the deflector pulley, which is located on end of the sliding rod. The belt is then carried over tension pulley on pulley carrier, and thence to motor pulley. The motive power from motor is transmitted to the main speed

control pulley, which operates upon the same shaft with the external and internal friction disc. These two discs are held together by tension provided through a friction spring, which tension is adjusted with a nut. The speed control friction disc (leather) operates between the external and internal discs. so that by turning the speed control knob in the proper manner, this will thrust the internal and external friction discs toward the revolving speed control disc, thereby increasing or decreasing the speed of the mechanism. The speed control friction disc operates upon the motor pinion stud, which contains the pinion gear, which in turn provides the motive power for the mechanism by engaging with the main driving gear.

The amount of friction prevailing between the friction discs determines the efficiency of the speed control. This friction is a fixed one on late machines while on older ones it is adjustable.

Too much friction results in unnecessary wear and added strain on all wearing parts.

On the end of the speed control farthest away from the machine will be noted a separate unit, comprising a friction disc, and controlling handle mounted upon a sliding carriage. It will be noted that this disc called the starting mechanism friction disc, runs loosely upon its bearing, and a close examination will show that the thickness of this disc is slightly more than the thickness of the speed control disc. Should the user desire to stop the machine without shutting off the motor or speed control and desire to again start the machine at the same speed that prevailed when stopping, it is only necessary to turn the speed control knob, which action will thrust the starting disc between the external and internal discs to a point where the space between these two discs is sufficient to allow the speed control friction disc to run free, thereby stopping the mechanism. To start the mechanism and instantly acquire the same speed at which the mechanism was stopped, it is only necessary to turn the knob, in the opposite direction, thereby withdrawing the friction disc and the mechanism is again in motion.

The use of this starting unit is particularly recommended where alternating current motor is used, inasmuch as the AC

motor does not pick up as rapidly as does the DC type of motor. Through the use of the starting unit it obviates also the necessity of shutting off the motor each time that the mechanism is required to stop.

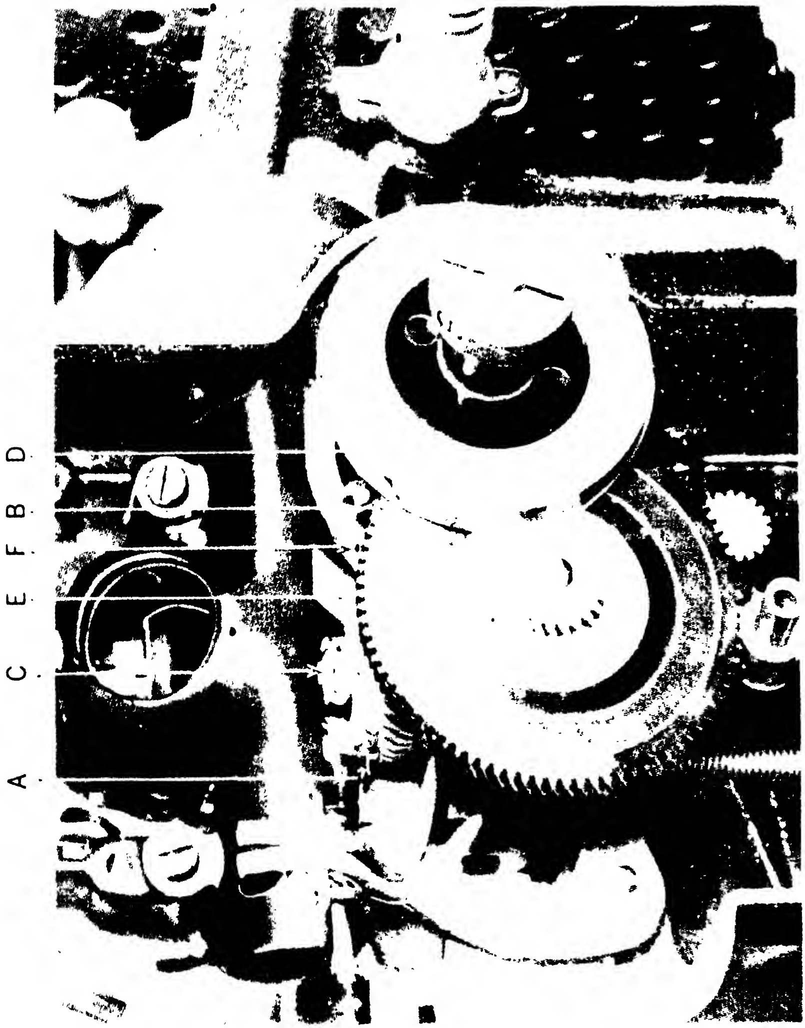
To Attach Speed Control to Simplex Projector

Push the framing handle upward and insert a long thin screw driver into open space directly under framing handle, and loosen motor drive pinion set screw. This screw should not be loosened so much that it will drop out, but just sufficiently to clear inside of the motor pinion bearing. Now loosen the main frame clamp screw, in the same manner as above. This screw must be unscrewed sufficiently to leave a clear bearing opening. Then hold speed control in the left hand with the friction disc, facing toward the screen. Now insert pinion stud into the hole of lower left door, and into the pinion bearing. It will be noted that the pinion gear is a part of the pinion stud. This gear is called the driving pinion and meshes with the main driving gear so in pushing the pinion stud into place make sure that both these gears are properly meshed. This can be done best by racking the gear slightly until the teeth engage, when the pinion stud may be pushed entirely into the bearing. At the same time, the bearing into which the clamp screw is threaded fits over the extended or protruding end of the pedestal arm pivot. The two connections herein must be made simultaneously and after this is done, tighten up the set-screw and clamp screw.

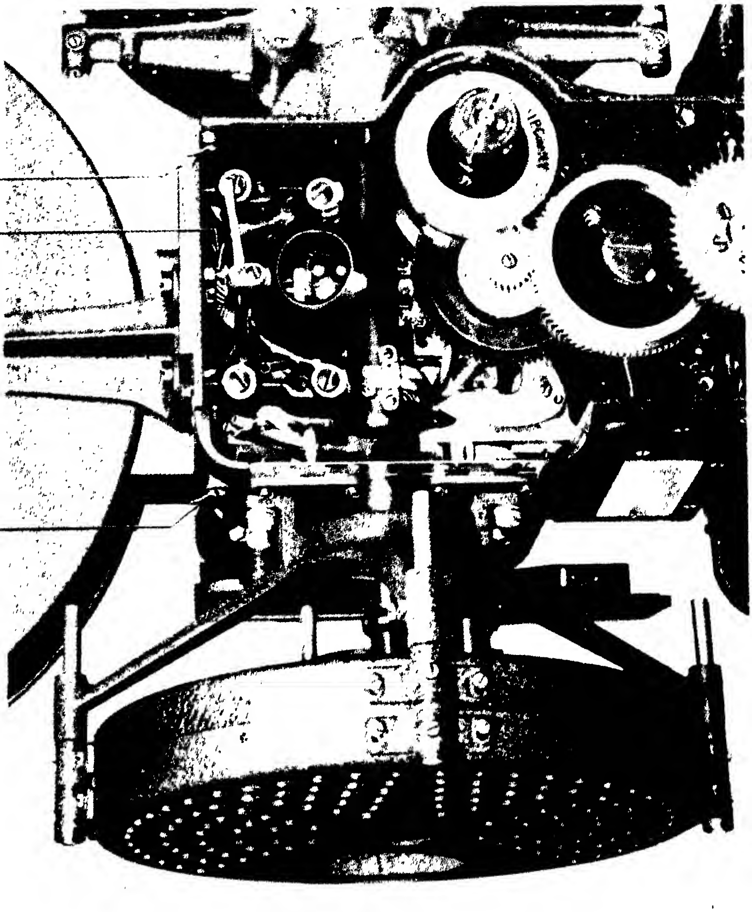
The tightening of these two screws is very important, as to operate the speed control with these screws loosened will result in positive gear damage. Now place motor belt onto the speed control, which belt arrangement is described in the foregoing paragraph. To tighten or loosen the belt tension, raise or lower the motor table.

Lubricating and Adjusting the Intermittent Movement

All lubrication for oil box end of the movement is applied through the main oil cup. (The one with the cap.) Through this oil cup the lubrication is distributed to the shafts, bearings,



A-Vertical Shaft Gear
B-Synchronizing Mark on Intermediate Gear
C-Synchronizing Mark on Vertical Shaft Gear
D-Synchronizing Mark on Intermittent Flywheel
E-Intermittent Movement Aligning Pin in Frame
F-Aligning Pin Hole in Intermittent Movement Case



A-Top Cover Plate Retaining Screws
B-Door Stop Screw

star and cam.

Before oiling, make sure that intermittent case is set with main oil cup pointing directly upward in a center position. Inject the oil into cup, meanwhile watching the glass oilsights on the cover of the oil box. When the oil level reaches halfway up on the glass oilsights, or to the mark, there is just the right quantity of oil in the box. The oil level should never reach the top of the glass oilsights; always halfway up on the glass.

The outer bearing of star wheel shaft is lubricated through means of ball oil cup located on top of flange of the outer bearing arm.

To Adjust Star

Remove the movement from the mechanism. Set movement down with main oil cup pointing directly upward in a center position. Make sure that the star is on the lock with the cam. Loosen (not remove) the six cover screws. The weight of the loosened cover pushes the star against the cam by gravity thus providing the necessary adjustment. This being accomplished, hold the cover firmly in position so that it will not move while screws are being turned. Give each screw a few turns at a time until the cover is firmly tightened up.

End Play on Fly Wheel

Loosen the screw in the knurled knob on the end of the fly wheel shaft. Insert a screw driver into the slotted end of the fly wheel shaft and turn the screw driver to the left to take up or decrease end play. If too tight, ease up by turning screw driver to the right. These directions are also stamped on the nut.

End Play in Cam

Remove the intermittent casing from the mechanism. Hold the fly wheel then turn the screw driver to the right, until knurled knob is clear of the threaded shaft. Pull fly wheel

off. Next remove the six cover screws. Take the cover off being careful not to tear paper gasket between the cover and case. Loosen the screw in the knurled collar on the end of the cam shaft. With the left hand holding the cam inside of the oil box, turn the knurled collar to the right with the right hand until adjustment required is obtained or until the shaft moves freely without the presence of any end play or binding.

End Play on Star Wheel Shaft

Loosen the two set screws in collar on the end of the star wheel shaft. With two fingers of the left hand, pull sprocket outward toward outer bearing while with the thumb of the left hand, push the collar inward against the outer bearing. While the collar and the sprocket are thus forced toward one another, tighten the set screws in the collar. Do not exert any undue pressure.

Removing Intermittent Sprocket

Remove the intermittent case cover. Remove the intermittent sprocket stripper. Remove the collar on the end of the star wheel shaft. Eject two sprocket pins with the sprocket-pin fixture. Do not hammer, drive or mutilate the sprocket pins. Hold the sprocket firmly and withdraw the star wheel and shaft out of bearing.

To replace simply reverse the procedure as described.

The movement is equipped with an intermittent sprocket stripper.

Intermittent Movement

The Simplex intermittent movement, the most important part of a projector mechanism, is of the Geneva type, and this movement is constructed with an accuracy of one ten-thousandth of an inch. There are no eccentric bushings and the star wheel shaft is supported on either end. The intermittent sprockets are cut on precision tooth cutting machines to insure

absolute accuracy. Sprocket strippers are regular equipment, these preventing the film from winding around the sprockets. The intermittent sprocket revolves on its own center when framing and therefore the distance between the aperture plate and the intermittent sprocket does not change—this distance is always 2¼ inches.

Film Trap

It is thoroughly reenforced to prevent warpage and is so constructed that the film tension shoes contact only with the celluloid base of the film. The danger of damaging the emulsion is thereby reduced to a minimum. Provision is made also to incorporate in the assembly the felt runner type of tension shoe which seems desirable in many localities. The film guide may be readily removed from the mechanism by giving it a slight upward thrust—this permits ease and free access to all parts of the trap and door for the purpose of cleaning away emulsion, dust or dirt.

Since the advent of sound film the Simplex Film Trap has been equipped with a slide-in mask which eliminates the projection of the sound track to the screen. By slipping this mask in or out as desired, silent, sound on disc, or sound on film prints may be properly projected at will. A gate locking device also forms part of this assembly. This assures that once the gate is closed it will remain positively locked in position during the projection of pictures. The gate may be readily released by a slight pressure of the finger when pressing on the opening device to which the lock is attached.

The fire shutter is of the gravity type, no friction being employed for its operation. It is controlled by centrifugal governors without springs and is, therefore, positive in action.

SIMPLEX E 7 PROJECTOR

Many radical changes have been introduced in this new projector, all of them tending to simplify the projectionist's work, and to secure a better screen picture. Increased illumination has been obtained by placing a second rotating shutter in front of the lens, this shutter being attached to the same shutter shaft and revolving in the same direction as the rear shutter, the shutter between the arc-lamp and the aperture plate of projector. By this design it is possible to cut off half of the light-beam behind the aperture plate, and half of the picture at the same instant in front of the lens, since the image is inverted after passing through the lens.

A steadier picture is obtained both vertically and laterally, first, through new developments in intermittent movement design, which allow far greater accuracy in manufacture, plus a hardened and ground intermittent sprocket on which the radii of the teeth are ground to extreme accuracy; and second, by the addition of edge-guiding in the film trap, which maintains the film in a constant lateral position and does not allow the film to weave slightly as in former designs.

Another new feature is the one-shot oiling system. This system consists of a piston pump which delivers at each impulse a metered quantity of filtered oil to a distribution system, where, by means of meter units, this measured quantity is proportioned to each bearing. Check-valves in the meter units prevent draining the oil lines between "shots."

The new projector is also supplied with a positive-action fire-shutter between the rear shutter and the film aperture,

which is operated through a centrifugally operated disk mounted on the revolving shutter shaft. When the projector is at rest this disc lies at an angle with relation to the shutter shaft, and when the projector is in operation, centrifugal motion straightens up, so to speak, and through a linkage device raises the fire-shutter out of the beam of light.

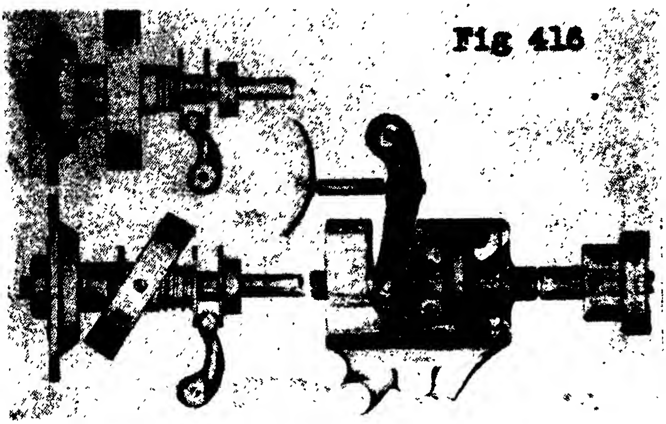


Fig 416

The projector is equipped with an automatic fire-shutter safety trip, which operates in connection with the automatic fire shutter and instantaneously drops the latter should a splice part at the intermittent sprocket. The unit is operated by the slightest increase in size of the upper film loop.

A framing lamp and spot sight box assembly is mounted between the rear shutter and the film trap. The lamp is lighted through a small mercoid switch and extinguished upon release of the fire shutter lever.

Positive synchronism, without backlash or lost motion, is assured between the intermittent movement and the revolving shutters when framing by a uniquely designed assembly shown in Fig. 416 The shutter shaft passes through an assembly similar to a cylinder and piston in automobile design, and fastened to the piston through a ball-race is the shutter driving gear, by means of which the shutter-shaft is driven through a Woodruff key. Attached also to the piston is a pivoted arm, the lower end of which

fetches up solidly against a plunger pin operated by the framing cam of the intermittent movement assembly.

The entire assembly is held under substantial tension by means of a heavy coiled spring, one end of which is held

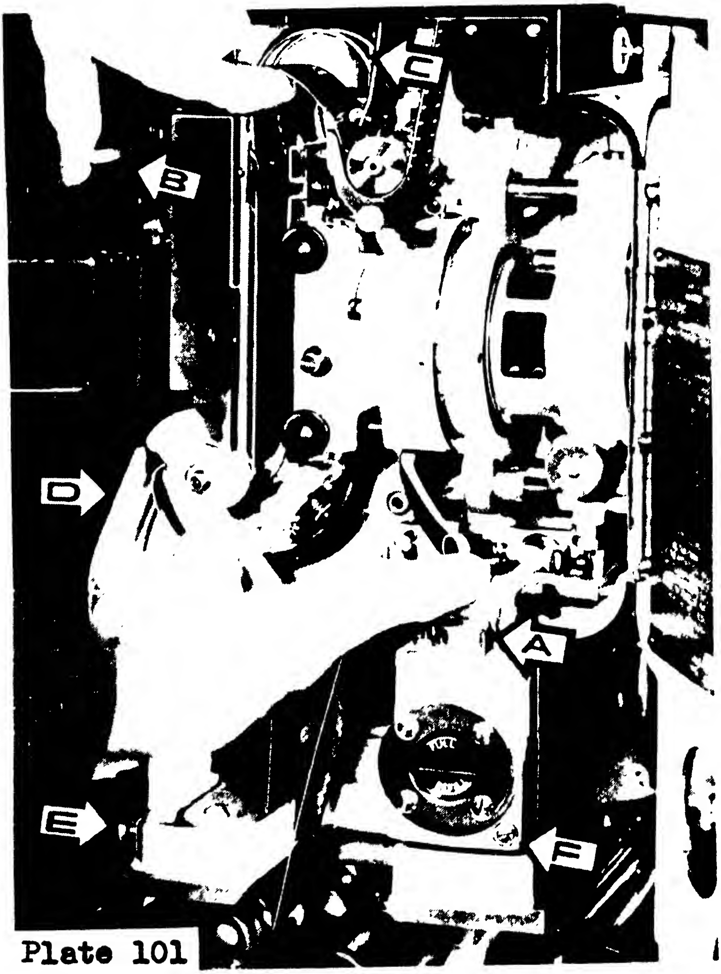


Plate 101

under tension by a collar on the shutter-shaft and revolving with it, and the other end of which fetches up solidly against the ball-race attached to the gear. This spring performs

two functions: it forces the piston rearward at all times, and at the same time removes any slight endplay in the shutter shaft and framing device synchronizing assembly.

In operation, when the framing handle is turned in one direction, the intermittent movement, complete with its

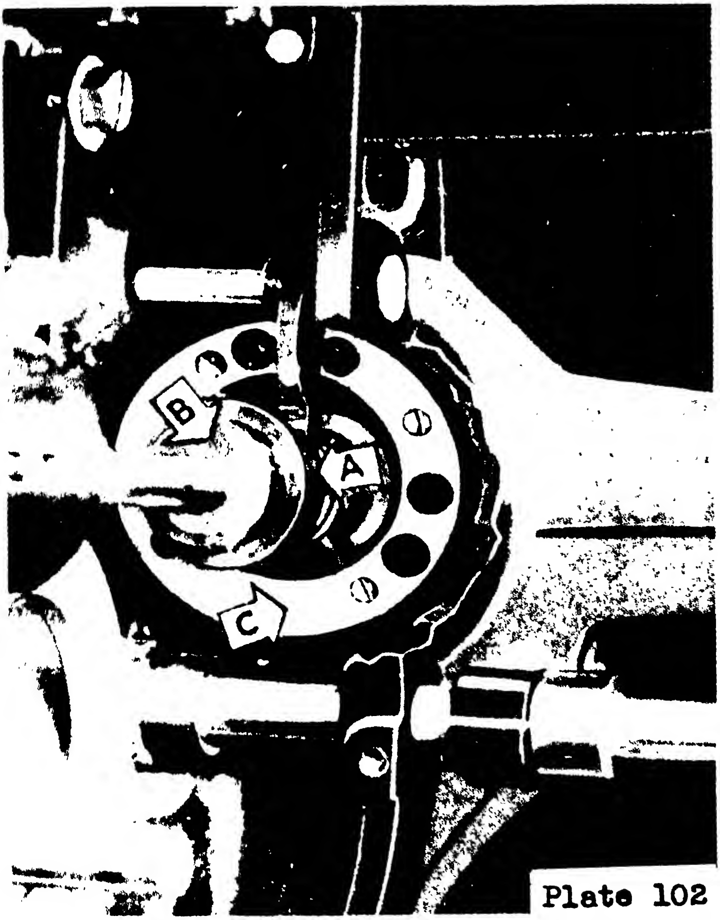


Plate 102

framing cam, revolves in its housing, forces the plunger against the pivoted arm, which in turn moves the piston and gear assembly forward against the spring compression, thus revolving the spiral gear and shutter-shaft the exact

amount necessary to maintain synchronism between the intermittent movement and the revolving shutters. When the framing handle is turned in the opposite direction, the entire assembly performs exactly the same function, except that the compression spring forces the piston and gear assembly rearward and thus the same synchronism is ob-

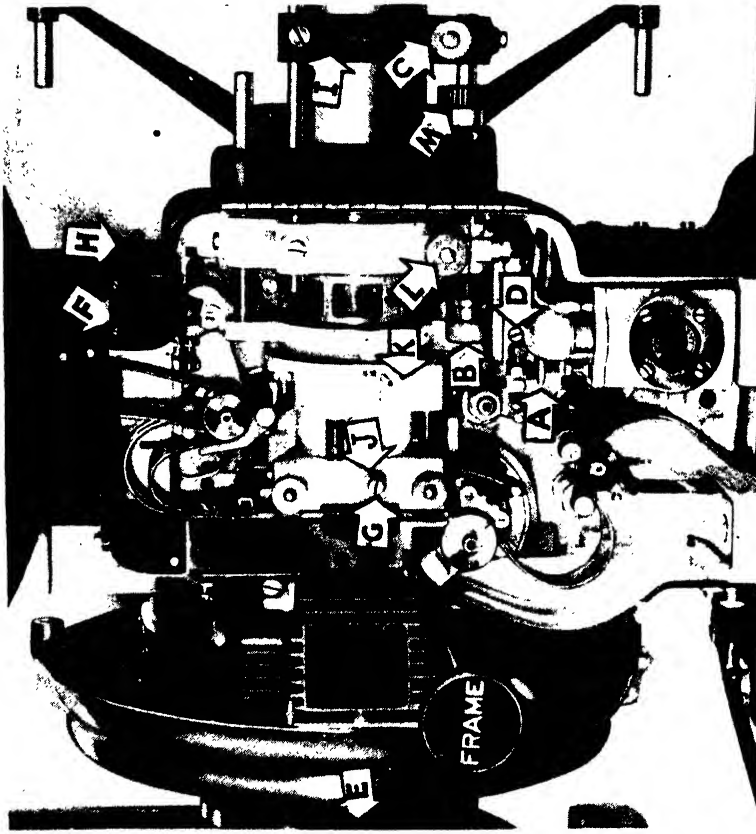


Plate 103

tained with any position of the framing handle and intermittent sprocket.

Lens focusing is accomplished from either inside or outside the mechanism, making it possible at all times to control readily the definition of the projected picture.

TAKING OUT THE INTERMITTENT MOVEMENT

Remove the spot sight box, film gate and film trap. Next remove right back drum cover, D, Plate 101, which is just below the film trap.

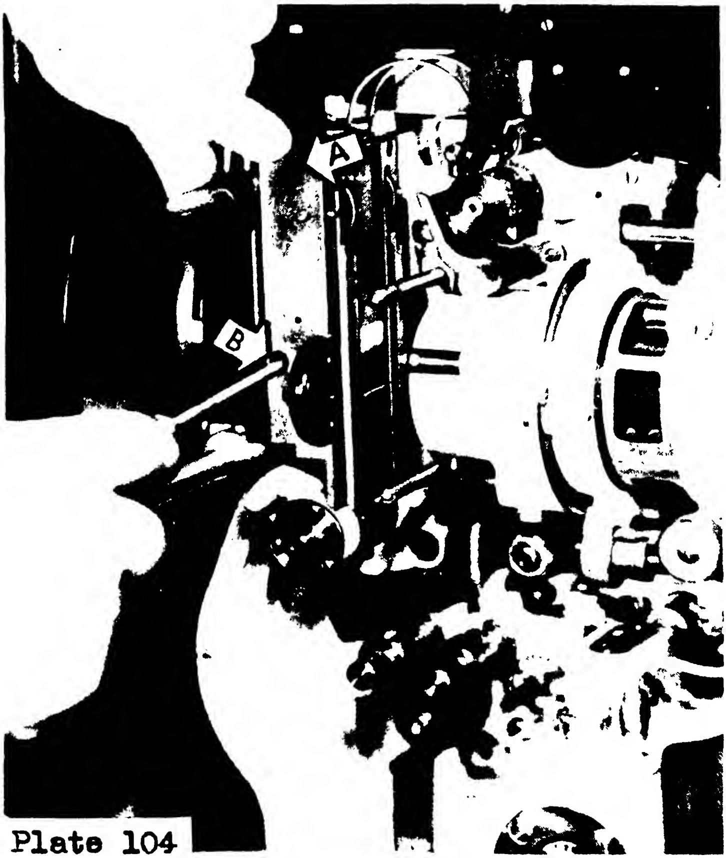


Plate 104

This casting is held by three knurled thumb screws, E, Plate 101, two along the bottom edge and one at the inner edge, half-way up. When these thumb screws have been loosened, draw the casting toward you.

At the non-operating side, loosen the clamping screws in the outer rim of the intermittent flywheel,

then remove the flywheel by drawing it off its shaft. It is important that you do not loosen the shaft screws in A, Plate 109. Now refer to A, Plate 160. Three wedge-shaped clamps hold the movement, and in turn are held by three screws, one of which is in contact with the

Plate 105

screwdriver in Plate 106. Loosen all three screws till the clamps swing freely. It is not necessary to remove any gears.

The third screw, hidden in Plate 106, behind the intermittent gear, can be exposed by operating the fram-

ing knob.

Swing the three clasps clear of the movement, relock the screws tightly to prevent the clamps dropping back into their previous position. Returning to the operating side, set the gate opening lever in open position, lift the fire shutter, and draw the movement toward you as shown in Plate 105.

INSERTING INTERMITTENT MOVEMENT

Make sure the case of the movement is clean, and that the surface of the synchronizing cam into which it fits, C, Plate 105, is also clean. Oil both lightly as a precaution against rust.

The procedure to be followed will differ slightly, according to whether the movement to be installed is a new one, or one that has been taken out of the same machine and merely is being replaced.

INSTALLING NEW INTERMITTENT

Take off its flywheel. Slide the movement into place from the operating side, lining up the guide lines B, Plate 105, so the guide lines on the movement and the guide lines on the framing cam coincide perfectly. Push the movement home when the small dowel pin in the framing cam will match up with the hole in the movement provided to receive it. Be careful to see that flywheel gear and large micarta gear are properly meshed while performing this operation.

REPLACING OLD INTERMITTENT

A movement that has been taken from the mechanism and is to be replaced, is slid part way into the synchronizing cam. Line up the guide lines roughly, deferring accurate alignment until later.

At the operating side look for an "O" mark on the intermittent gear hub, just outside the gear, and a corresponding "O" mark or dot on the micarta gear that meshes with the intermittent gear.

Rotate both gears until the teeth indicated by these "O" marks are in contact with each other. Now push the movement all the way into the synchronizing cam.

Leaving the gears at the drive side properly meshed, as indicated by the "O" marks, return to the operating side and rotate the movement in the synchronizing cam until the guide lines are perfectly matched and push the movement home.

INSERTING INTERMITTENT MOVEMENT

Whether the movement is a new one or an old one, it is now set properly in the synchronizing cam, and ready to be locked in place.

This is done by means of the wedge-shaped clamps on the driving side, all three of which are swung into the slots provided for them on the intermittent casing.

The holding screws are then tightened. The flywheel is replaced on the intermittent shaft, the key in the flywheel fitting into the guide groove on the shaft. The flywheel clamping screws A, Plate 109, are tightened evenly. The rear casting of the housing, the film gate, film trap and spot sight box are now replaced.

In the case of a new movement it is still necessary to "time" the shutters. It is as well, even when replacing an old movement to check the shutter tc see that it is correctly timed.

TIMING THE SHUTTERS

Loosen shutter and adjusting slide fastening screw. Turn the shutter adjusting knob at the front of the projector, under the exterior lens collar, until the shutter synchronizing device lock screw D, Plate 103, is in approximately central position in its slot. Remove the aperture plate.

Loosen the lens collar locking knobs C, Plate 103, and remove the lens and air deflector slide E, Plate 103, then loosen both clamp screws on both front and rear shutters, leaving those shutters free to turn on their shafts. Remove the spot sight box.

Insert the shutter aligning barrel in the lens holder with the knurled screw toward the front shutter. Lock it in place with the lens collar locking screws. Insert the shutter aligning shaft in the aligning barrel with

the grooves toward the front shutter, lifting the fire shutter out of the way and being careful not to strike the aligned shaft against either front or rear shutter blade.

Line up the narrow groove in the shaft, the one nearest the front of the shaft, with the front of the aligning barrel. When this is properly done, and the knurled screw is tightened down, the lower end of that screw will enter the wider of the two grooves on the shaft, holding the shaft in place, but leaving it free to rotate even when the knurled screw has been turned as far as it will go. Rotate the shaft until its flat extension faces downward. Set the movement in its locked position by turning motor flywheel or knob on end of motor shaft, not by the shutter shaft knob.

Take the intermittent indicator and hold it vertically, with the diamond-shaped end upward. Slip the diamond over the axis of the intermittent sprocket shaft, which protudes beyond the double bearing arm.

Turn the mechanism over by hand, in the normal direction very slowly, watching the lower end of the intermittent indicator. Stop when the indicator just commences to move.

Grasp the rear shutter by its hub clamp and turn it until the edge of one blade, either blade, comes up against the flat extension of the shutter aligning rod. Be sure the shutter is free so as not to turn the mechanism. While turning the shutter hub, push it toward the projector, to assure that it will remain clear of the shutter guard. Lock the shutter in this position.

Turn the front shutter assembly similarly until the edge of either blade comes up against the flat extension of the aligning shaft, making sure the shutter remains centered with reference to its guard, so it will not rub. Lock the front shutter in position.

Remove the shutter aligning devices from the lens holder and remove the intermittent indicator.

Replace the aperture plate, spot sight box and lens, and do not forget to refocus the lens.

A slight adjustment may be necessary to remove any travel ghost.

CHANGING THE INTERMITTENT SPROCKET

The sound drive should first be disengaged, and the projector turned over by the front shutter knob, to note the "feel" of the mechanism, for comparison when the job is completed.

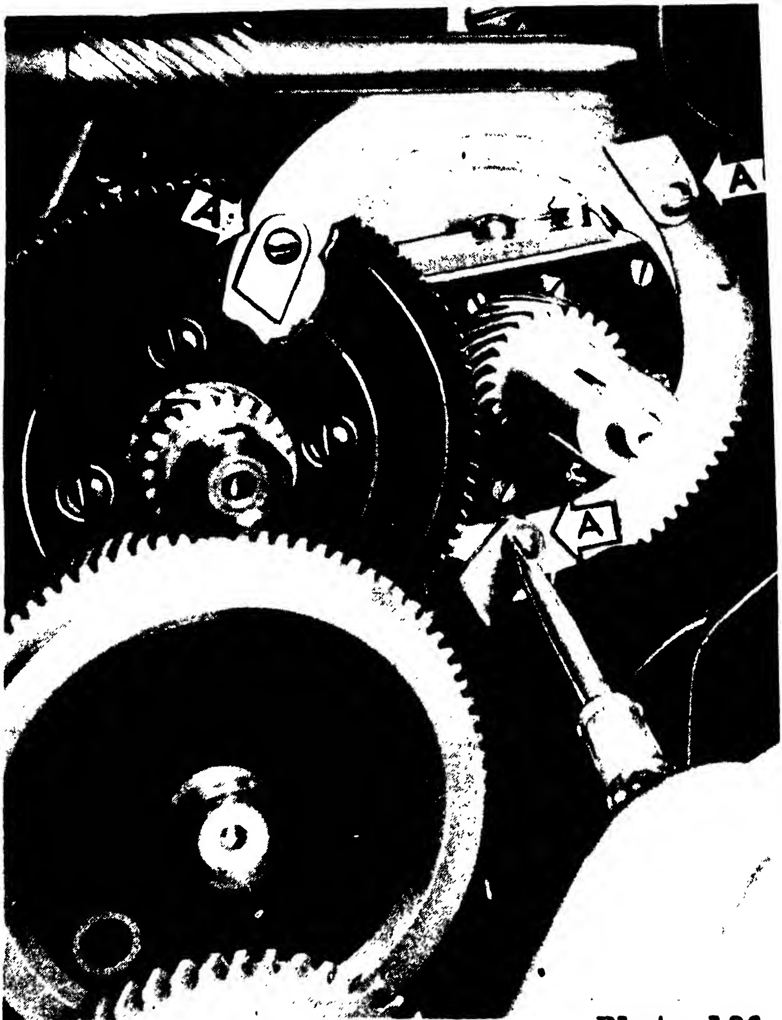


Plate 106

Remove the film gate, the film trap and the housing casting just under the film trap.

The screw under the right hand oil sight of the movement is then taken out, and the oil drained into absorbing material. Oil that reaches the mechanism should be wiped away.

The four screws in the same circumference are then removed, after which the double bearing sprocket arm can be drawn out. This must be done with extreme care to avoid striking the star wheel as it leaves the intermittent casing. The gasket between the arm and casing must be preserved undamaged, or replaced with a new one.

The fastening screw in the sprocket hub is then removed, and the star wheel and its shaft, is drawn out of the double bearing arm. Lift the sprocket out of the arm, and replace it with a new one. Slide the star wheel shaft back into position.

This is done very gently, with a slight twisting motion, no tools are used to drive the shaft. If the fit is snug, the shaft may be lubricated with a drop of oil. When the screw holes are lined up, the fastening screw is replaced in the sprocket hub, but before it is tightened down, the sprocket and star are pressed toward each other until there is no perceptible end play, but rotation is still perfectly free. Replace gasket.

The double bearing arm is now held in the left hand, the fingers of the right hand resting against the sprocket. In this way, and with due care to avoid striking the star the left star wheel is brought gently against the cam. The left hand now rotates the double bearing arm carefully, until a locating hole in its casting engages a corresponding locating pin in the frame of the movement.

Pin and hole are kept in approximate contact while the fingers of the right hand rotates the sprocket very slowly until they feel the star engage the cam radius. The arm is then gently brought home into position. The locating pin and hole, star and cam, engaging simultaneously.

With the arm in place, the five screws are restored, and tightened down evenly. They are then loosened again to allow the arm to shift downward on its own weight, and then the screws are again tightened.

The projector is now again turned over by the front shutter knob to determine whether there is the slightest trace of binding between the star and cam. Unless this action is absolutely perfect, the five screws are loosened, the arm moved slightly, and the screws retightened. This process is repeated as many times as found necessary until the star and cam action has been brought to perfection.

The intermittent oil reservoir is then re-filled, the gate, the trap and the housing replaced.

REPLACING THE UPPER FEED SPROCKET

Take out the spot sight box, the gate and film trap. Then with a short screwdriver, reach through the hole in the upper sprocket shoe and remove the fastening screw from the sprocket hub. The gear and shaft can then be drawn out from the driving side. Be careful not to lose the thrust washer, that is between the main frame and gear. The sprocket is lifted clear and the shaft is slid back into place through the hub of the new sprocket. The fastening screw is replaced. While this screw is being tightened down, the gear and sprocket are pressed toward each other to leave approximately .002 inch end play. Replace the gate, trap and sight box.

REPLACING THE LOWER FEED SPROCKET

Remove the housing casting below the film trap.

With a short screwdriver, loosen the screw that holds the upper stripper stud in the main frame casting, tilt the stripper out of the way.

Remove the fastening screw in the sprocket hub, and draw the sprocket off the shaft.

The new sprocket should be slipped all the way in, leaving only approximately .002 inch end play, and the fastening screw made tight with the sprocket in this

position.

The shaft may be pushed in from the non-operating side, through a hole in the large main drive gear. The stripper is tilted back into place, care being taken to see that it just clears the sprocket hub and its fastening screw.

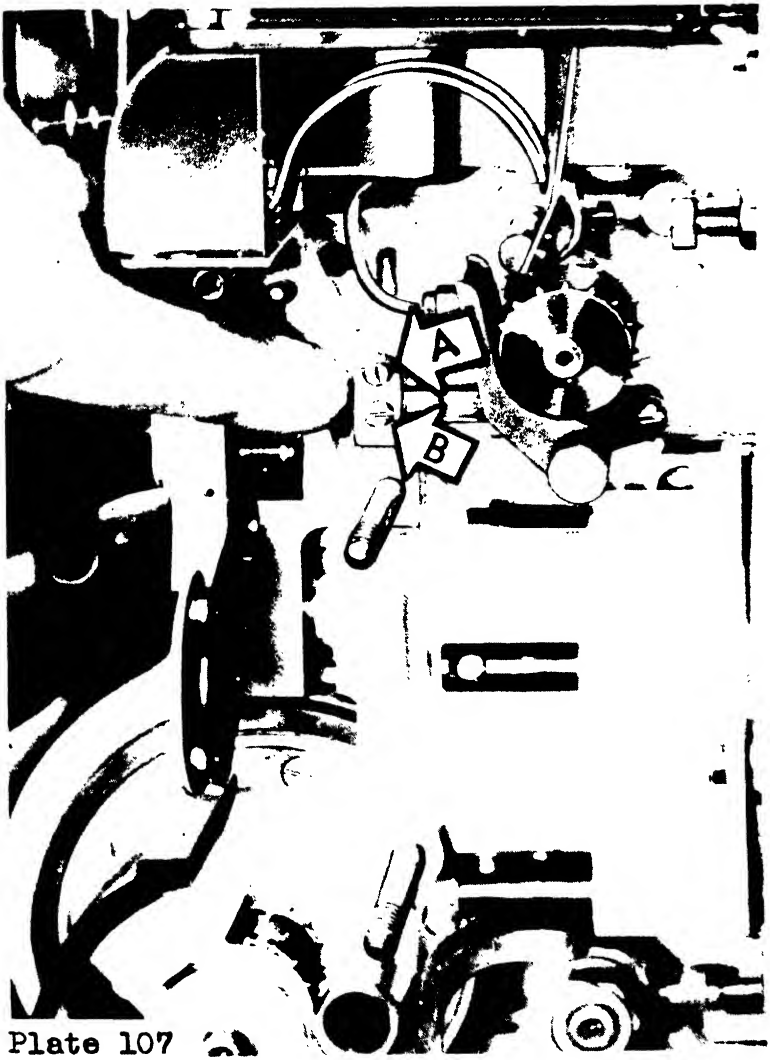


Plate 107

REPLACING MAIN, INTERMITTENT GEAR STUDS

Take off the gear as already described. Insert a punch into the oil hole on non-operating side of the mechanism and at the operating side loosen and remove the stud self-locking nut or film protecting stud, with a suitable wrench. The stud E or F, Plate 110, can now be drawn out from the driving side. Oil the new stud and restore operation.

REPLACING GATE TOP TENSION PAD

In the case of the removal of the intermittent drive gear assembly stud, time the shutters as already described.

Take out the gate and remove the small screw at the center of the retaining screw A1, Plate 108. Remove the round knurled nut B1, Plate 108, the pad tension adjusting nut, and the spiral spring.

Slip off the tension pad. Slip on the new one, restore the spring, knurled nut and adjusting screw.

REPLACING INTERMITTENT SPROCKET SHOE

Take out the gate and remove the small screw at the center of the bottom spiral spring, the sprocket shoe tension retaining screw, A2, Plate 108.

Remove the knurled nut (the sprocket shoe tension adjusting nut B2, Plate 108) and the spiral spring.

Slip off the shoe and replace, restoring the spring, the knurled nut and adjusting screw. Adjust the tension.

REPLACING LONG TENSION PAD

Remove the four gate casting holding screws, C, Plate 108. Separate the gate plate E, Plate 108, which is located by two dowel pins, from the casting and proceed as already described for Replacing The Gate Top Tension Pad.

REPLACING LOWER SPROCKET DRIVEN GEAR AND SHAFT

Take off the main drive gear. At the operating side of the mechanism loosen the holding screw in the lower sprocket hub, as described in Replacing Lower Feed

Sprocket.

The gear, G, Plate 110, and the shaft can now be drawn out from the driving side of projector.

REPLACING THREADING LAMP

Take out the two screws in the face of the threading lamp shield, F, Plate 103.

The 120 volt bulb, a standard 6 watt, candelabra base type, can then be unscrewed and replaced.

REPLACING FRAMING LAMP

Take out the sight box and hold it upside down. Pressing on a nickel-plated stud that will be found near the rear of the spot sight box, will lower the framing lamp within easy reach. The bulb is a Mazda No. 55, 6-8 volt bayonet base type.

REPLACING MAIN DRIVE GEAR

Remove the lower housing casting on the drive side. Take out the collar fastening screw in the main gear shaft, slip off the collar and draw the gear L, Plate 109, toward you.

Lubricate the new gear with a drop of oil. When installing it, rotate the lower feed sprocket until its gears meshes with the new main drive gear, then restore the collar, holding screw and housing casting.

REPLACING INTERMEDIATE DRIVE GEAR ASSEMBLY

Take off the intermittent flywheel. Take off the main drive gear, take out the collar fastening screw in the intermediate gear shaft, slip off the collar, and draw the gear assembly, K, Plate 109, toward you.

Lubricate the new assembly with a drop of oil on each gear. In installing it, after meshing all gears properly make sure there is no end play. Restore the collar and fastening screw, the main drive gear and the intermittent flywheel. Retime the shutters.

REPLACING UPPER SPROCKET DRIVEN GEAR

Proceed as explained under Replacing Upper Feed Sprocket, taking out gear C, Plate 109, and shaft from

the driving side.

Lubricate the new gear and shaft with a drop of oil.

REPLACING UPPER FEED SPROCKET SHOE

Do not attempt to take the shoe off the arm on which it is mounted. The entire arm must be removed

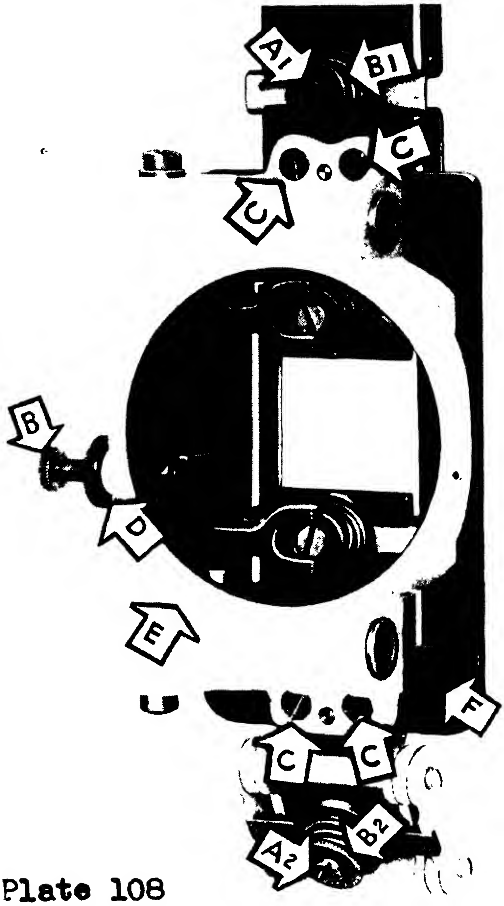


Plate 108

from the mechanism. The stud on which the arm rides is loosened with a screwdriver and drawn out with pliers. The arm can then be removed.

The shoe is mounted in the arm by means of a shoe stud and the browned machine screws. One screw holds the shoe stud, the other holds the shoe itself. Take both screws out of the arm, being careful not to lose the washer on the screw.

The shoe and its stud will now come off. Slip the stud through the new shoe and replace it in the arm. Replace and tighten down the stud holding screw, pressing on the stud at the same time to remove end play. When this screw is tight the shoe should be free to rotate on its stud, but with no end play at all. The shoe locking screw and the washer, is now replaced, but is not yet tightened down.

The arm and arm stud are now replaced in the mechanism, aligned so the shoe rides properly on the sprocket, and is then locked in place.

The shoe is then rotated on its own stud until the inner curvature of the shoe parallels the curve of the sprocket, and the shoe holding screw is then tightened down.

Above and a trifle to the left of the arm stud will be seen a hexagonal bolt and lock nut. These are adjusted to leave exactly two thicknesses of film clearance between sprocket and shoe, and the lock nut is tightened down.

REPLACING THE LOWER SPROCKET PAD ROLLER

Loosen the lower sprocket and roller arm stud screw, F, Plate 105, and draw screw and stud toward you. The pad roller arm can then be taken out.

Loosen the holding screw of the shaft of the roller to be removed, after which the shaft, with its roller, can be drawn out of the arm. Insert the shaft in the new roller and replace in the arm. Allow the roller about .005 inch play, and tighten down its shaft holding screw. Replace the arm in the mechanism and restore the arm stud and the holding screw. In tightening this screw, press inward on the screwdriver to remove all end play from the arm.

At the top right of the arm will be found a hexo-

gonal bolt and lock nut. Adjust these for exactly two thicknesses of film clearance between sprocket and the left roller, regardless of which roller was changed.

ADJUSTING GATE PLATE

Remove gate. Loosen the gate guide rod adjusting screw, B, Plate 107, and release the gate guide rod adjusting screw, A, Plate 107.

Work the gate opening lever back and forth while adjusting gate guide rod adjusting screw, until the desired degree of friction is obtained.

Then tighten the locking screw and replace the gate.

NOTE: Two thicknesses of motion picture film measure approximately .015 of an inch.

REMOVING THE SPOT SIGHT BOX

This is removed from the operating side of the mechanism merely open the door of the projector and draw the spot sight box toward you.

REMOVING THE REAR SHUTTER GUARD

The rear shutter guard is built in two vertical sections or halves, each of which may be removed separately.

To take off the half at the operating side, take out the machine screw seen at the bottom of the shutter guard, when facing it from the operating side.

Take out the corresponding screw at the top of the guard. Going now to the drive side of the projector, two machine screws will be seen facing at the bottom of the guard. The one nearest the mechanism is taken out, the corresponding screw at the top of the guard is taken out. The operating side of the guard can then be lifted out.

To take out the drive side half, remove both machine screws facing you at the bottom of the drive side of the guard, and both machine screws facing you at the top of the drive side. Take out the nickel-plated hexagon bolt just above the drive side framing knob. The drive side of the shutter guard can then be lifted off.

REMOVING THE FRONT SHUTTER GUARD

At the top of the guard take out one machine screw, the one at the very top, and furthest to the front.

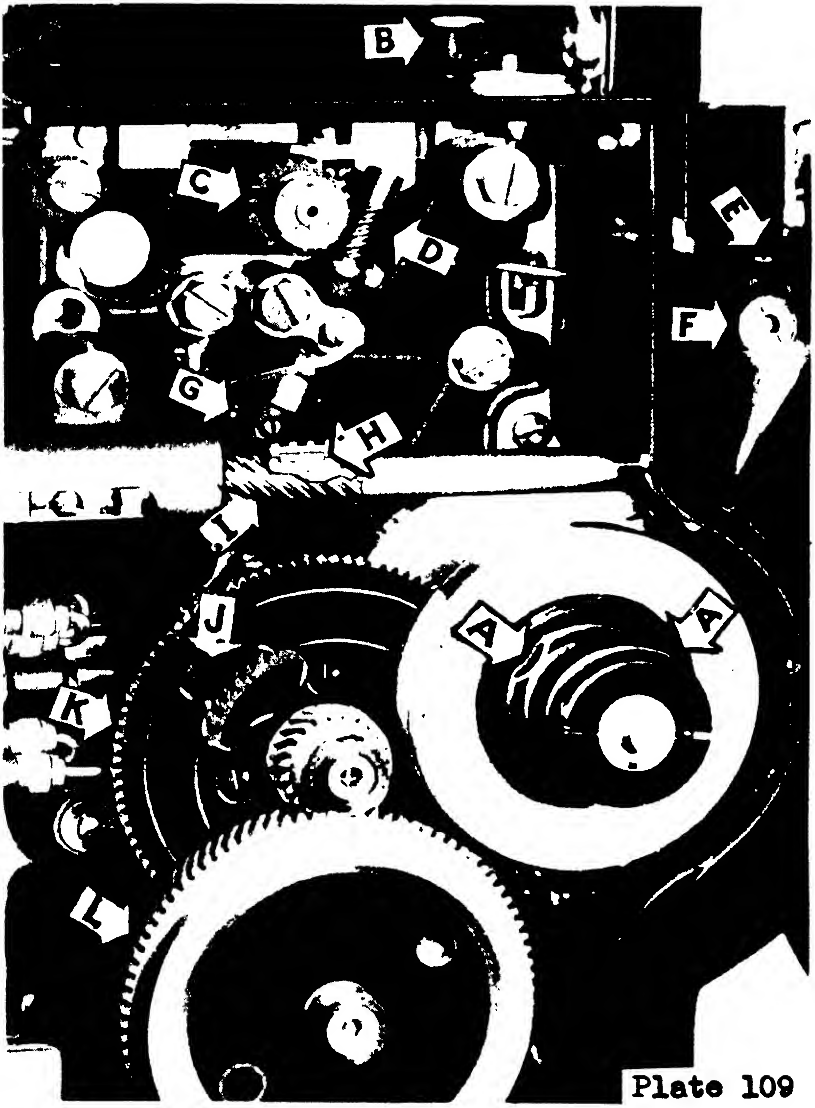


Plate 109

Take out the corresponding screw at the bottom, the one furthest toward the bottom and furthest front. At the drive side remove the machine screw furthest toward the drive side. The front half of the guard can then be removed.

If the rear half of the shutter guard is to be removed, loosen the shutter hub clamping screws and draw the front shutter off its shaft. At the top of the guard take out the top-most screw. Proceed similarly at the bottom and the drive side, again removing three screws in all. The rear half of the guard can then be drawn off the shutter guard support rods.

REMOVING THE FILM GATE

Put the gate in half-open position, by operating the gate-opening lever. Take off the knurled thumb screws at the top and bottom of the gate. Draw the gate toward you.

To replace it, again operate the lever to half-open position. Push sliding shield in lens mount forward. Engage the hole in the bottom of the gate with the lower stud, and slip the gate into position, then replace the knurled thumb screws.

REMOVING THE FILM TRAP

Remove spot sight box, as already described, hold up the fire shutter by means of lift lever and remove the rear retaining screw with a thin screwdriver, as shown in B, Plate 104. Next remove the front retaining screw, the one indicated by the left forefinger in A, Plate 104. Lift the fire shutter and draw the trap toward you.

ADJUSTMENT OF FIRE SHUTTER

Remove spot sight box. Look down between the rear of the mechanism and the rear shutter guard to locate the fire shutter lift pin fastening screw. This is a black screw, the lowest than can be seen. Loosen it.

At the non-operating side of the mechanism, look in past the governor to locate the fire shutter lifting pin, a steel pin about 1/8 inch in diameter which en-

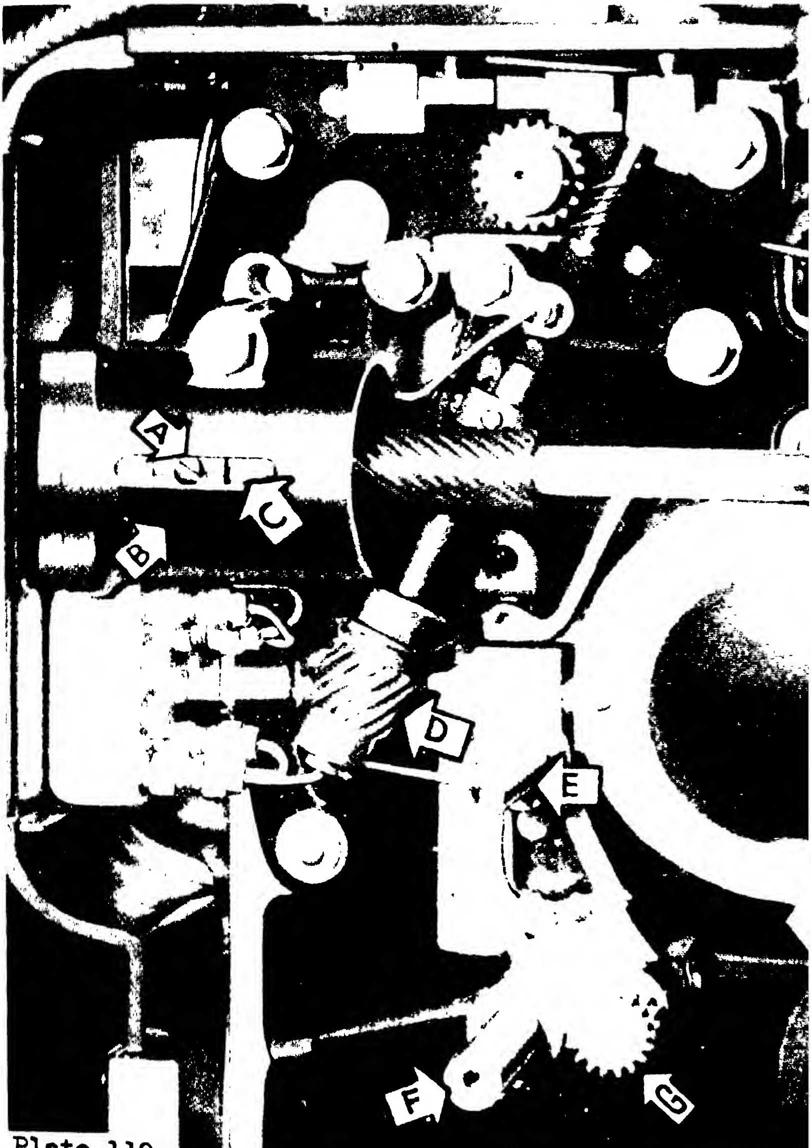


Plate 110

gages the slot that raises the fire shutter. Lift this pin as high as possible, making sure it remains in its slot, hold it in that position and re-tighten the fastening screw. Run the projector without film, and try to push the fire shutter down by hand without using too much force. If it can be made to drop, the adjustment was not properly made, and must be repeated.

ADJUSTMENT IF FIRE SHUTTER JAMS

Remove the spot sight box. Just above the top of the fire shutter on the film trap there is a small stud or excrescence on the film trap casting. The top of the fire shutter in raised position, should not quite touch this stud, but should clear it by about 1/32nd of an inch. Loosen the fire shutter raising lever adjusting bushing lock screw, E, Plate 109, about 1/4 turn, no more. Do not take out this screw. Now adjust the shutter height by turning the fire shutter raising lever adjusting bushing, F, Plate 109. Turning this bushing clockwise raises the shutter, turning it counter-clockwise lowers the shutter. Turn down the lock screw when the proper adjustment is obtained.

ADJUSTMENT IF FIRE SHUTTER FAILS TO TRIP

The fire shutter trip C, Plate 101, should be operated manually from time to time to make sure the shutter is working properly.

If it does not, take out the spot sight box and the film trap, according to instructions already given in these charts. Remove the shutter lever guard holding screw and take off shutter lever guard. Shutter mechanism can now be cleaned with kerosene to remove gummed oil.

SIMPLEX MODEL SI PROJECTOR

FRAMING AND THREADING LAMP

The framing and threading lamp is 10 watts, 120 volts candelabra base, and is wired through the shielded cable provided to any convenient source of 110 volts AC or DC.

LUBRICATION

Before operating the projector lubricate the mechanism as shown in the oiling chart. All oil holes and cups are painted red. Never under any circumstances attempt to lubricate the mechanism while the projector is running.

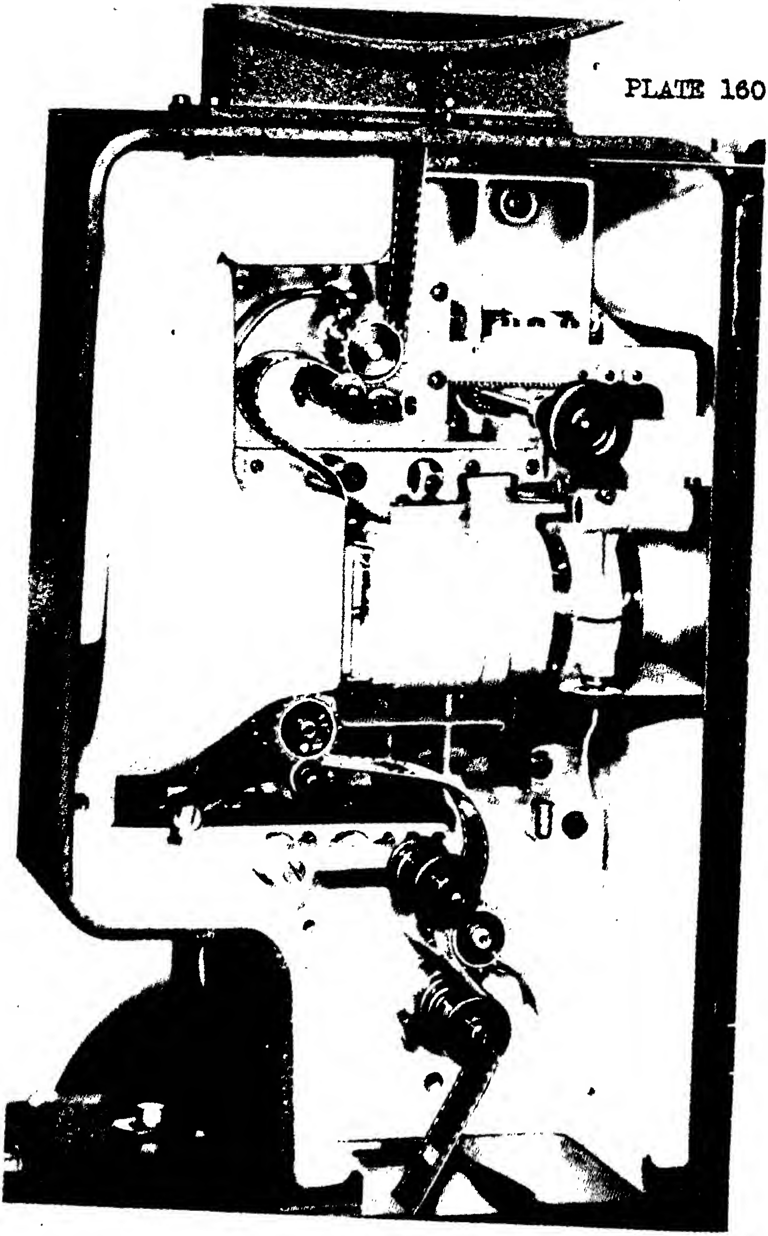
TO INSERT PROJECTION LENS

Turn the projector over by hand until the front shutter blade is clear of the lens opening. Insert the lens, or the lens in its adapter, in the lens holder. Turn lens focusing knob so that the lens collar is in the center of its travel with equal focusing leeway forward and backward. Strike the arc and focus lens as accurately as possible, opening and closing the fire shutter momentarily by hand to watch the results on the screen. When the outline of the aperture plate is in focus on the screen fasten lens securely in lens mount. All of this should be done with the mechanism not running, and without film. Make certain that the lens barrel not only clears the front shutter but that there is sufficiently clearance to allow the lens to be brought forward into focus after film has been threaded into projector.

THREADING

Pull out light shield located between aperture plate assembly and lens holder. Open film gate. Frame move-

PLATE 160



ment approximately three-quarters to the front for ease of threading. Open pad rollor arms and then proceed to thread as shown in Plate 160. These threading instructions apply to all soundheads with the exception of the W. E. 209 and 211, for the threading of which see Plate 162.

Be careful not to make the upper film loop too large or this may trip the automatic fire shutter.

CLEANING

Owing to the white enameled interior, illuminated by the threading lamp, and the ease with which parts may be removed the mechanism is easily kept clean. All foreign matter that may accumulate in and around the mechanism should be removed at once.

REPLACING UPPER FEED SPROCKET

Turn upper feed sprocket film stripper sufficiently so that it clears the sprocket. Loosen sprocket fastening screw and pull sprocket off the shaft. Put the new sprocket with sprocket set screw on shaft. Pull end of shaft toward you and push sprocket toward non-operating side of mechanism then tighten set screw and allow approximately .002" end play. Turn stripper into position so that the end of the stripper plate is below the sprocket rim, being sure that it clears both the sprocket and the sprocket fastening screw.

REPLACING INTERMITTENT SPROCKET

Turn intermittent sprocket film stripper sufficiently so that it clears the sprocket. Remove the intermittent sprocket fastening screw and nut and carefully remove intermittent sprocket from its shaft. Replace the new sprocket and insert screw and nut. Pull end of star wheel toward you and push sprocket away from you, tighten screw, allowing .002" end play.

SETTING FRONT AND REAR SHUTTERS

First remove the four screws holding upper cover on non-operating side of mechanism. Loosen the two screws in the flanged hub of the rear shutter. Loosen

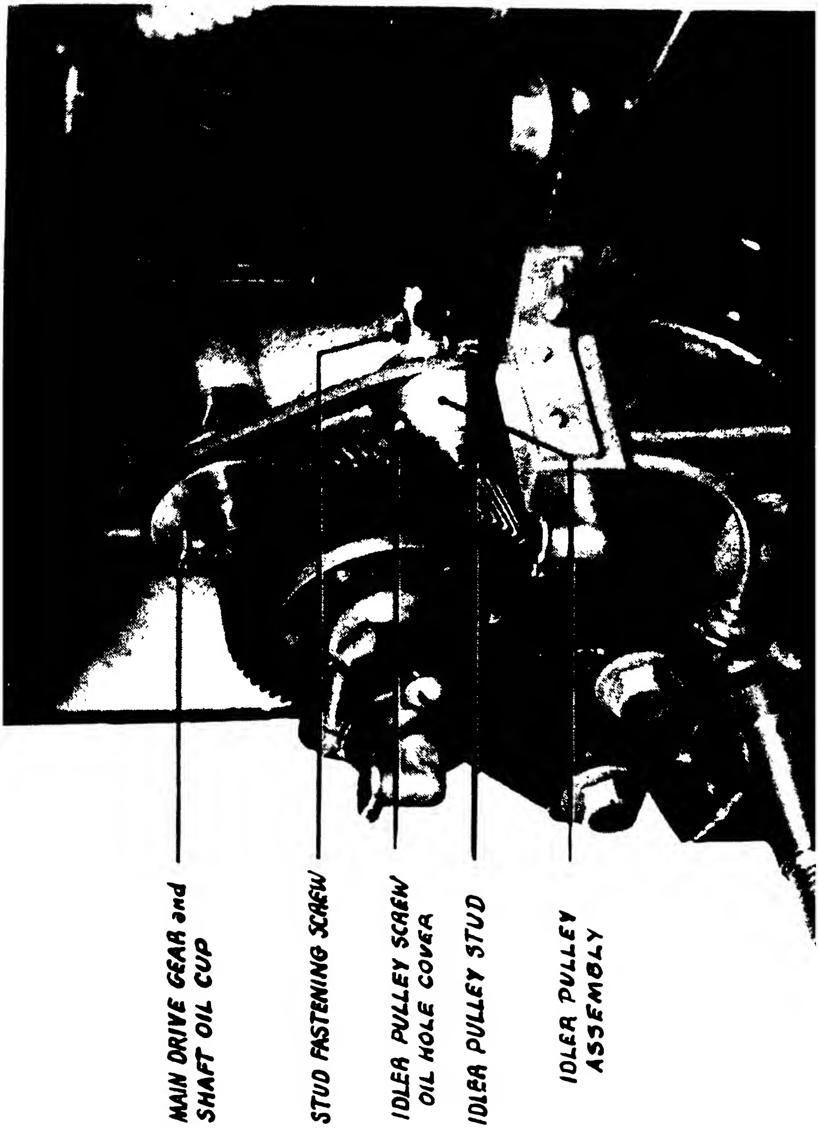
the two screws of the flanged hub in the front shutter so that the shutters move freely on the shaft. Insert the long shutter setting rod through hole provided in upper left-hand portion of the main frame and through the holes in the front shutter guards, being sure that the setting rod clears or passes through the opening in the front shutter, also that the front shutter flange fastening screws are in a convenient position for fastening. Fasten long shutter setting rod by means of screw provided in main frame of mechanism. On the non-operating side turn the rear shutter manually on its shaft until the heads of the fastening screws point toward you. Insert the short shutter setting rod through the hole provided in the upper right-hand section of the main frame and then through the hole in the air deflector adjoining the rear shutter and fasten same with screw provided in the main frame. Turn mechanism over manually very slowly in the normal running direction until the star and cam are in a locked position, in other words until the intermittent sprocket stops turning.

Slip the movement indicator over the end of the intermittent sprocket shaft. Again turn the mechanism over slowly until the indicator just begins to move.

Facing the front of the mechanism, turn the front shutter in a clockwise direction by its hub clamp until the edge of the blade comes up against the shutter setting rod. Maintain the shutter firmly in this position and solidly fasten the two screws in the shutter flange hub, thereby locking the shutter fast to the shaft.

Facing the rear of the mechanism turn the rear shutter in a counter-clockwise direction until the edge of the shutter blade touches the rear shutter setting rod, then securely fasten the two screws in the shutter hub, locking the shutter to the shaft.

Remove movement indicator from intermittent sprocket shaft. Also loosen screws holding both long and the short shutter setting rods and be sure to remove rods from mechanism. Replace the upper door on non-operating side and its four screws.


MAIN DRIVE GEAR and
SHAFT OIL CUP
STUD FASTENING SCREW
IDLER PULLEY SCREW
OIL HOLE COVER
IDLER PULLEY STUD
IDLER PULLEY
ASSEMBLY

TO ADJUST TENSION ON FRAMING DEVICE

Remove upper cover on non-operating side by removing the four fastening screws.

Slightly loosen fastening screws on the hub of the framing knob located near the main frame on the non-operating side of the mechanism.

TO INCREASE TENSION

Tighten the screw in the center of the framing knob.

TO DECREASE TENSION

Loosen this same screw. When the desired tension has been obtained, tighten the screw which has been only slightly loosened. Replace cover with four screws.

TO REMOVE INTERMITTENT MOVEMENT

Remove door (upper) on non-operating side of the mechanism by taking out the four screws.

Remove the flywheel from flywheel shaft by taking out one long screw located on the outer rim of the flywheel; also remove one short flywheel fastening screw located on hub between flywheel and flywheel gear. The flywheel can then be readily removed from the shaft.

Next remove rear shutter guard from operating side of mechanism. This is accomplished by removing one fastening screw located below the automatic fire trip rod and the other located at the bottom of the shutter guard casting.

Open light shield and remove film trap assembly by taking out the short screw holding the film trap casting to the main frame; also remove the long screw that passes through the upper loop film guide.

Then remove the two screws that are located at the very bottom of the intermittent movement and which fasten the movement to the support casting.

Be sure that the screws just above the ones in question are NOT removed inasmuch as they fasten the front section of the intermittent case to the rear half.

Then remove the screw in the upper right-hand portion of the movement (slightly to the right of the intermittent movement oil cup) and the other screw located at the upper left-hand corner of the intermittent movement assembly.

TO REPLACE MAIN GEAR AND LOWER SPROCKET DRIVE

Remove both upper and lower covers on non-operating side by means of eight screws holding same in place.

Remove collar by removing fastening screw; pull off main drive gear.

TO REMOVE LOWER SPROCKET DRIVE GEAR ASSEMBLY

Open lower pad roller arm. Loosen lower sprocket stripper and move out of the way of lower sprocket.

Remove fastening screw located on hub between steel and bakelite micarta gear. Pull lower sprocket shaft out from operating side of mechanism while holding on to the lower sprocket drive gear.

TO REPLACE LOWER SPROCKET DRIVE GEAR

Hold lower sprocket gear assembly against the main frame in line with the lower sprocket shaft bearing.

Push lower sprocket and shaft from operating side of mechanism through the gear assembly.

Then insert and tighten gear fastening screw and allow .002" end play. Readjust film stripper.

TO INSERT INTERMITTENT MOVEMENT

Remove flywheel and gear from movement as per the instructions already given.

Attach intermittent movement unit to its supporting casting by means of four screws. This procedure has already been explained. Do not fasten the screws too tightly and slide the complete movement as far as possible toward the rear shutter.

Then slide flywheel and gear on to flywheel shaft line up holes in flywheel and gear assembly with the

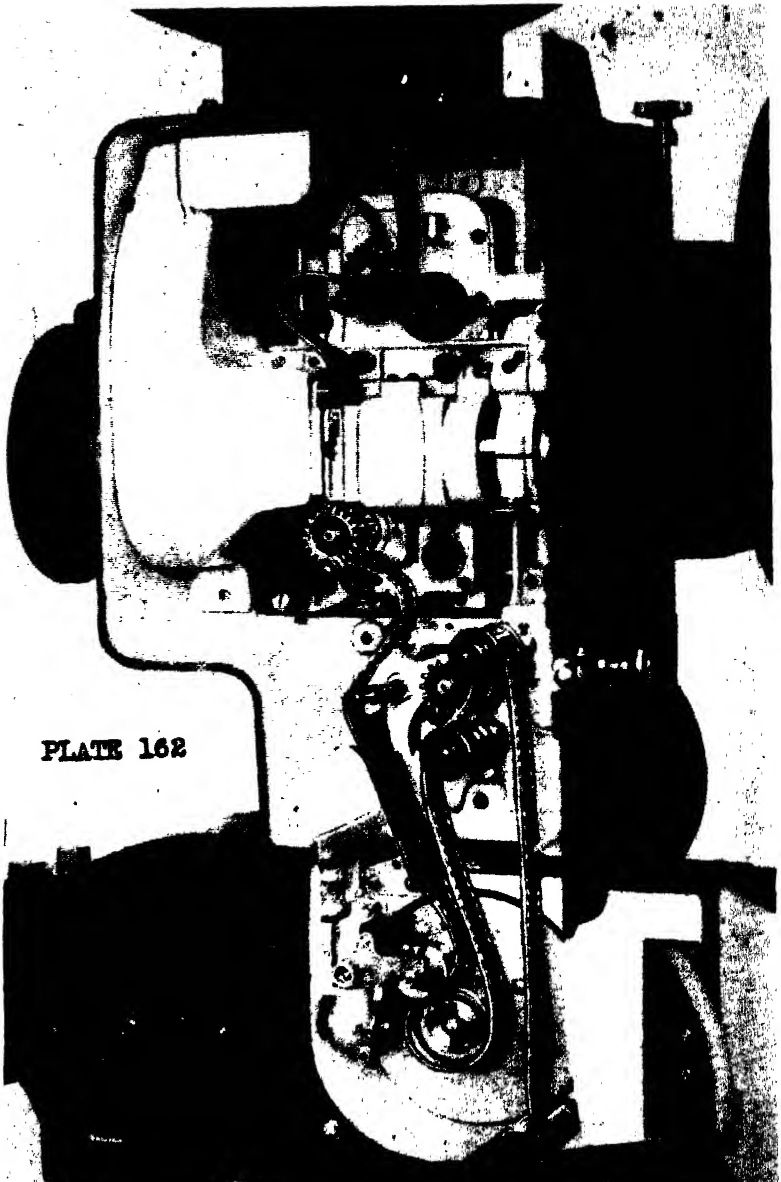


PLATE 162

hole in the flywheel shaft; insert short screw but do not fasten tightly at this time. Now insert the long screw in the outer rim of the flywheel, and securely fasten both of these screws.

Next move the complete intermittent movement toward the oblique shaft gear on the non-operating side until they are properly meshed.

Make sure that the gears do not bind, nor should there be too much play between them.

When the above operations have been completed tighten the four screws holding the movement to its support casting.

Check gear mesh to be sure that they have not changed position while these screws were being fastened.

Now shut shutter as already outlined. Replace film trap assembly with one short and one long screw referred to elsewhere.

Replace internal rear shutter guard by means of the two fastening screws.

Replace upper cover on non-operating side by means of the four screws.

LUBRICATION

While the mechanism is new it should be lubricated approximately every four hours, with the exception of the intermittent movement and upper sprocket and shutter drive assembly, the oil levels of which should be checked occasionally to see that the proper levels are maintained.

As time goes on the intervals of lubrication are gradually lengthened and when the mechanism is broken in, it will require lubrication once a day.

The gears and the governor should be oiled at least once a day while the mechanism is new.

Do NOT attempt to lubricate the mechanism while the projector is in operation.

SOUND MECHANISM LUBRICATION CHART

DAILY

FILL OIL CUP CAREFULLY WITH SIMPLEX OIL.

DAILY

ADD SAE #40 OIL AS REQUIRED TO MAINTAIN OIL LEVEL SHOWN WHEN MECHANISM IS AT REST.
(ADD OIL ONLY AFTER MECHANISM HAS BEEN IDLE OVERNIGHT. DO NOT FILL TO RED LINE AFTER INITIAL FILLING WHEN INSTALLED.)

MONTHLY

APPLY 1 DROP OF SIMPLEX OIL TO THE OIL HOLE IN EACH PAD ROLLER.
(ROTATE PAD ROLLER TO DISTRIBUTE OIL.)

MONTHLY

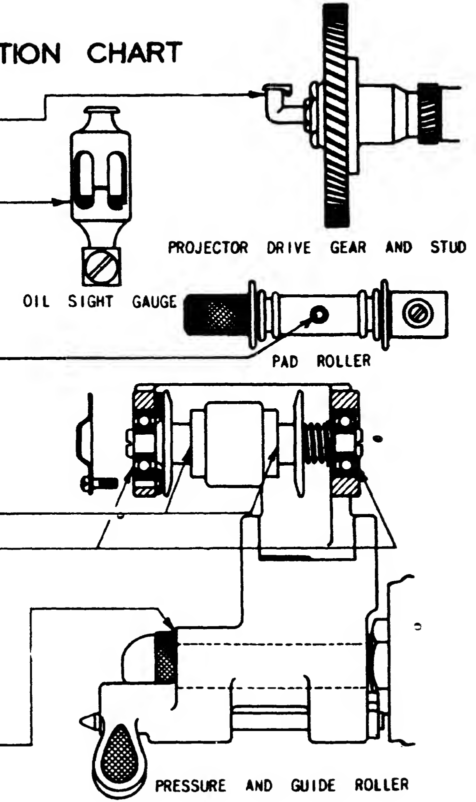
APPLY 1 DROP OF SIMPLEX OIL TO THE SHAFT AT EACH END OF THE ROLLER. (ROTATE FLANGES TO DISTRIBUTE OIL.)

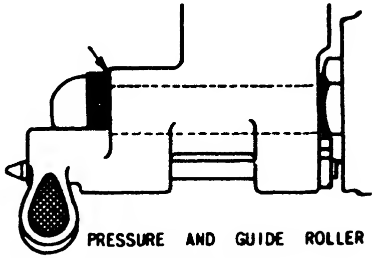
SEMI-ANNUALLY

APPLY 1 DROP OF SIMPLEX OIL TO EACH BALL BEARING.
(ROTATE BEARINGS TO DISTRIBUTE OIL.)

MONTHLY

APPLY 1 DROP OF SIMPLEX OIL TO THE SHAFT. (SLIDE ASSEMBLY IN TO APPLY OIL. OPERATE TO DISTRIBUTE OIL.)

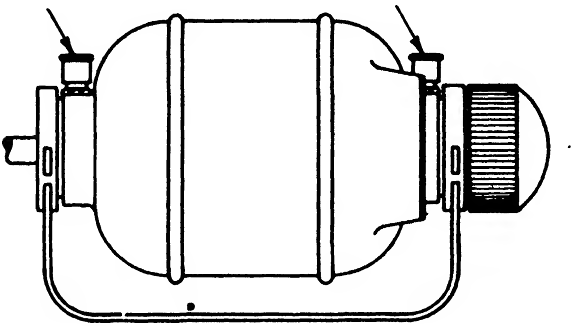




PRESSURE AND GUIDE ROLLER

MONTHLY

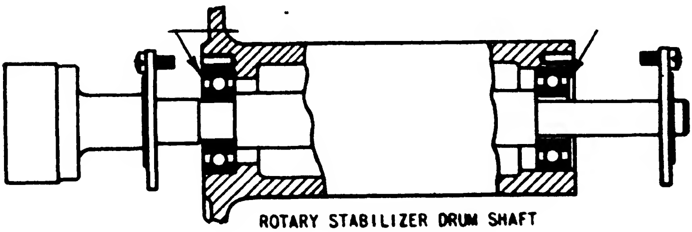
APPLY 1 DROP OF SIMPLEX OIL TO THE SHAFT. (SLIDE ASSEMBLY IN TO APPLY OIL. OPERATE TO DISTRIBUTE OIL.)



PROJECTOR DRIVE MOTOR

MONTHLY

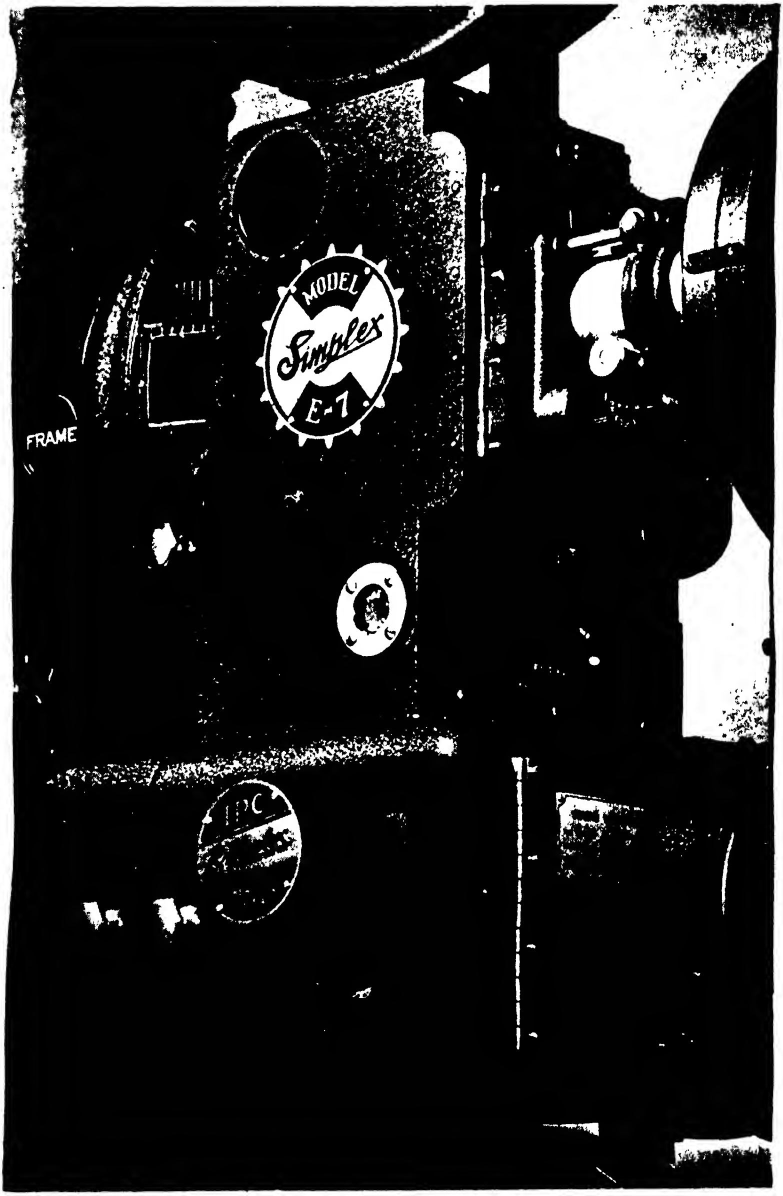
GIVE EACH GREASE CUP ABOUT 1/2 TURN. DO NOT FORCE TOO MUCH GREASE INTO THE BEARINGS. REFILL WITH SIMPLEX REAR SHUTTER GREASE AS REQUIRED. MARFAK #2 (TEXACO) MAY BE USED AS A SUBSTITUTE.



ROTARY STABILIZER DRUM SHAFT

SEMI-ANNUALLY

APPLY 1 DROP OF SIMPLEX OIL TO EACH BALL BEARING. (REMOVE DAMPING WHEEL AND TWO RETAINER RINGS. ROTATE BEARINGS TO DISTRIBUTE OIL.)


MODEL
Simplex
E-7
FRAME

SIMPLEX SOUND REPRODUCING SYSTEM

In analyzing the requirements of film reproducing systems for the theater, the Simplex reproducing equipment has been divided into four groups, viz., the sound mechanism equipment, control equipment, power amplifier equipment, and loud speaker equipment.

The tabulation is divided into three horizontal sections representing the small, the medium, and the large theaters, and at the head of each equipment group are shown the salient requirements or "constants" of design. Under "Sound Mechanism," regardless of the size of theater, the equipment is to operate with 35-mm film running 90 feet a minute; it is to reproduce standard track and be adaptable to push-pull and "dual track" reproduction with simple modification; it must come up to speed in 2 to 3 seconds, and the flutter and weave should be held to the same low limits. There are no "variables"; that is, there is no reason to relax on any of the requirements for smaller theaters. Thus one policy of the design is established—the sound mechanism shall be identical for the small, the medium, and the large systems.

The new Simplex sound systems are available in three classes, Type "A," Type "B" and Type "C," these being in turn suitable for use in small, medium or large sized theaters.

Two-way speaker systems with multicellular high-frequency horns and folded low-frequency horns are employed in all three systems. The small system employs one "A" type high-frequency unit and one "B" type low-frequency unit. The medium system employs two "A" type and two "B" type units, and the larger system, two "C" type and four "D" units. The "C" and "D" units differ from the "A" and "B" mainly in power-carrying capacity. Fig. 405

shows a schematic diagram of the system. The systems are made for two-projector installations, but a third can be added, as shown by the broken lines. The power unit supplies exciter lamp power for two or three projectors. The central equipment consists of one volume control and change-over unit, for each projector. The outputs of the

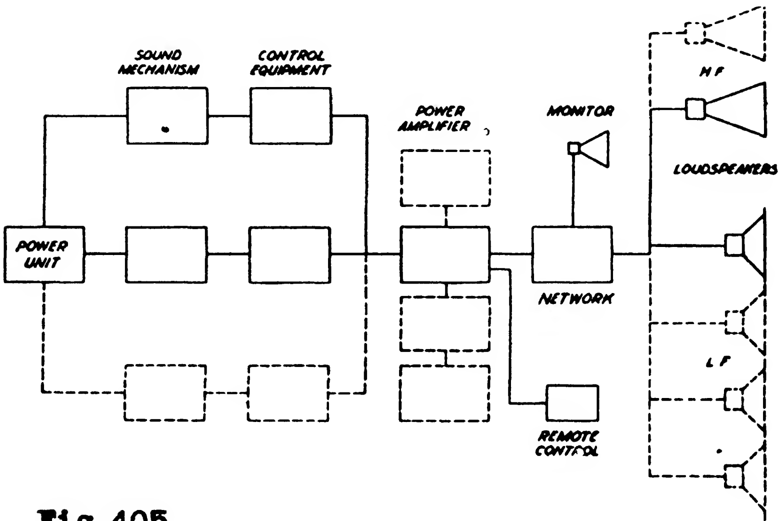


Fig 405

volume control amplifiers are connected to the main power amplifier, the single-unit amplifier is used in the small system. In the medium-size system another amplifier is added as indicated by the broken lines in Fig. 405, and in a still larger system the third and fourth amplifiers are added as shown. The two-way network and the monitor speaker in the projection room are shown in solid lines, as they are used in all three systems. The loud speakers for the small system consist of one low-frequency and one high-frequency unit. For the larger systems, to accommodate the increased power of additional amplifiers, greater power handling capacity is provided by adding high- and low-frequency units.

The number of mechanical contacts in the sound circuit from the photo-electric cells to the loud speaker voice-coil

has been reduced to a minimum. The main amplifier gain adjustment and the sound change-over have been placed in isolated circuits. The main amplifier gain adjustment is in the feed-back circuit and the change-over is accomplished by bias control in the volume control amplifier.

Fig. 406 shows the sound mechanism, operating side. Film motion past the scanning light-beam is controlled by the well-known rotary stabilizer principle, insuring constant

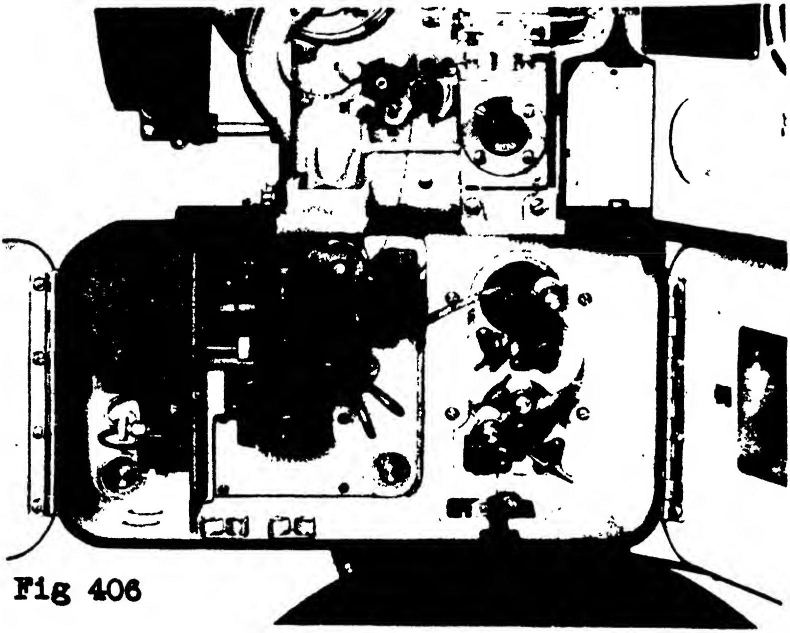


Fig 406

speed. The 4-ampere, 9-volt pre-focused exciter lamp, of new design, has a short, sturdily supported filament minimizing vibration. The exciter lamp is easily removable and is designed to permit vertical and lateral adjustments for exact positioning of the filament. The exciter lamp compartment is well ventilated, and careful shielding prevents any stray light from entering the photoelectric cell compartment.

An oil-proof optical system projects a uniformly illuminated 0.084 x 0.0012-inch image upon the sound track. A

micrometer adjustment is provided for focusing. The light reflector is a highly ground and polished mirror, which

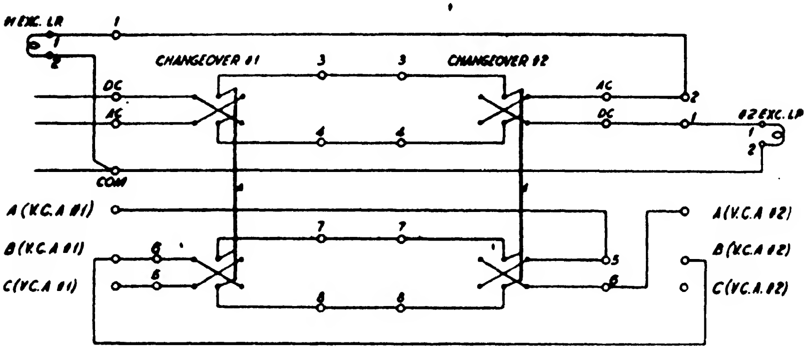


Fig 407

directs the light-rays to the photo-cell. The reflector is adjustable and easily removable for cleaning.

The photocell is vertically mounted, eliminating vibration and microphonic noise. It is located away from the sprockets and out of the way while threading the projector. The front of the housing is hinged so that it can be opened easily, exposing the cell completely. The connecting wires are cambric covered to eliminate trouble ordinarily caused by oil on wires.

Lateral film guides and pressure rollers are equipped with a trigger control. By pushing down on a lever the roller locks in position, and by a slight touch on the lower lever it is tripped open. The film compartment door can not be closed with the roller in open position. This is a safety feature.

The "sound bracket" is a unit assembly consisting of the exciter lamp, optical system, rotary stabilizer, scanning drum, reflector, and photoelectric cell and is rigidly mounted on a heavy bracket attached to the main frame.

The drive motor is a cradle-suspended $\frac{1}{4}$-hp., split-phase induction motor with ball bearing mounted rotor, and thrust bearings on both ends. There is a manually operated brake

which quickly stops the machine in case of film breakage.

The film-drive sprockets consist of a sound sprocket and a hold-back sprocket, to prevent the reflection of take-up jerks from disturbing the film at the scanning point. The drive mechanism is in one assembly. It consists of the gear-box, sprockets, shafts, and rollers, and stripper plates, all of which are easily removable as a single unit.

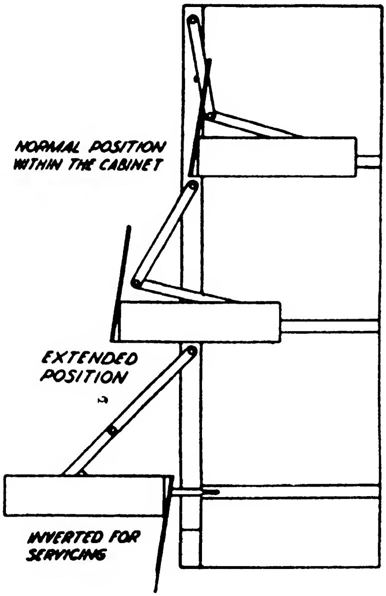


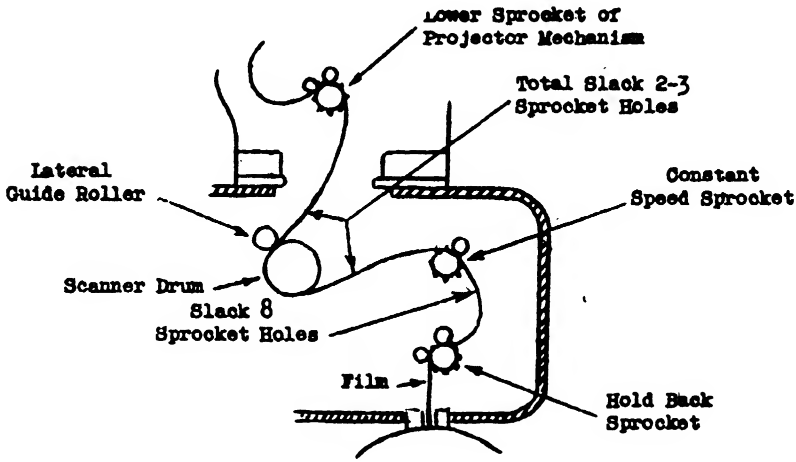
FIG. 408

The amplifier consists of a two-stage resistance-coupled voltage amplifier employing RCA 6J7 tubes. It has 46-db. gain. Its normal operating position is 26-db., which puts the volume control mid-range. The volume control having nineteen steps of 2-db. each.

Fig. 407 shows schematically the circuit of the electronic sound change-over, which comprises a three-way switching arrangement, one at each projector, to control the bias of the second stage of the volume control amplifier. This method of change-over control eliminates relays and mechanically interlocked switches; it is instantaneous and

noiseless, since it avoids the necessity of breaking the signal circuit.

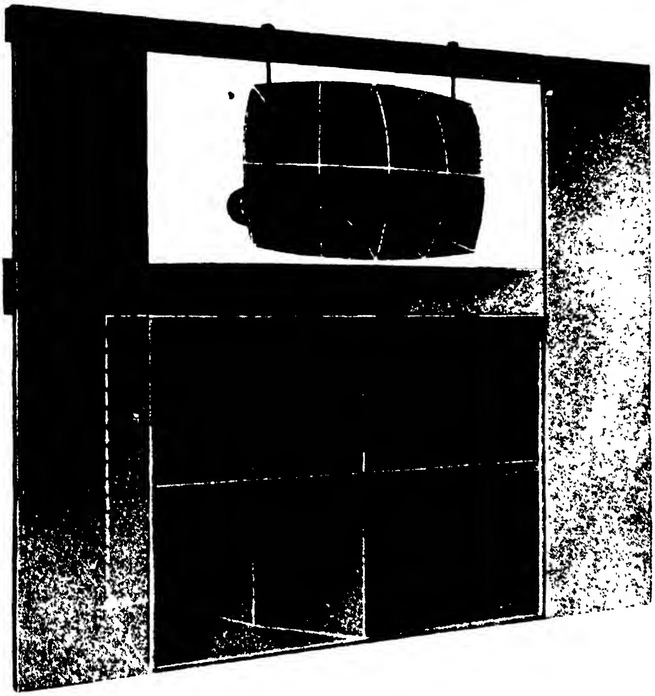
The main cabinet is a three-section unit designed for wall or floor mounting. In a signal-cabinet installation it is usually mounted on the wall. Where two cabinets are used, one is placed above the other mounted on a set of feet. Each unit in the cabinet may be partly withdrawn and rotated 180 degrees for examination or servicing while in operation, as is shown in Fig. 408; which schematically shows the arrangement of the cabinet. Three chasis posi-



tions are shown, the normal position within the cabinet, the position when withdrawn before rotating, and the inverted position after being rotated 180 degrees.

The power amplifier employs resistance coupling interstage. The power output is 15 watts at frequencies as low as 50 cycles, with less than one per cent total harmonic distortion. A meter is mounted in the power amplifier panel for testing the condition of the tubes. The scale on the meter is blocked off in red and green sectors. Green means the tube is all right, and red indicates that replacement of the tube whose number appears in the red block is desirable.

The exciter lamp power unit employs two 2-ampere Tungar bulbs to furnish direct current held within close limits, variations in line voltage being compensated for by a ballast lamp regulating circuit. The lamp of the operating projector is connected to the rectified output of the power unit while the lamp of the "off" projector is connected to a transformer at one-fourth the normal a-c operating volt-



age. On change-over the circuits are automatically switched. Using alternating current on the "off" projector provides a more economical arrangement for several reasons: first, the lamp life is preserved; second, the rectifier construction and power consumption are less expensive. Furthermore, by the same facilities and by simple operation of one switch, the lamps may be operated on alternating current at normal rating, thus providing an emergency operating

condition in the event of failure of the rectifier circuit. The a-c circuit employs a separately fused transformer and circuit that permit testing and inspecting the rectifier while the system is in operation, a-c operation of the exciter lamp also provides a very convenient test circuit for balancing the photoelectric cell output when adjusting the sound mechanism for reproduction of push-pull sound tracks, that is to determine the cancellation effect.

The loud speaker network couples the amplifier output to the two-way loud speaker system with a 400-cycle cross-over. The control panel incorporates two switches, marked "HF" and "LF" which permit high- or low-frequency speakers to be operated as separate groups. This feature is of special value in testing and for continuing operation in the event of failure of any speaker unit. Where more than one high- or low-frequency speaker is used, additional selective switching arrangements may be added for further flexibility. The panel also includes the monitor loud speaker volume control and a jack for headphone monitoring. The volume control of the monitor loud speaker can be adjusted from the amplifier location, which is usually mounted near to the projectors. With the "HF" and "LF" switches set to disconnect all loud speakers, a terminating resistance is automatically connected across the amplifier output, permitting a volume indicator or output meter to be conveniently plugged into the monitoring jack for checking the amplifier frequency characteristics. When the "HF" switch only is operated, so that the high-frequency loud speaker leg is disconnected, the network is automaticallv by-passed, and the low-frequency loud speaker operates directly from the amplifier output as a full range speaker, thus permitting emergency operation. When only the "LF" switch is operated, so that the low-frequency loud speaker leg is disconnected a resistance is automatically substituted for this speaker unit, thus permitting the high-frequency speaker to continue operation in the normal manner.

The low-frequency speaker is a folded exponential horn of solid wood construction. The low-frequency unit is of the permanent-magnet dynamic type.

The high-frequency loud speaker assembly consists of a

multicellular exponential horn of new design employing a spherical mouth opening and eight-cell construction for high quality and wide angle distribution.

SIMPLEX PU-1000 POWER UNIT

This is an all AC operated chassis type power unit weighing 65 lbs. Two terminal strips on extension cable forms are provided for external connections. The unit is in two parts, one unit is an all AC operated, full-wave rectifier, using two SN-722 or SN-941 Tungar Bulbs and one SN-723 Ballast Lamp. The SN-941 Tungar Bulb is a "soft" bulb, and is preferred to the earlier "hard" bulb. This unit supplies 4 amperes, 9 volts DC to the "ON" exciter lamp in the sound mechanism. The other unit is an AC step down transformer which supplies 2 volts AC to preheat the "Off" exciter lamp, and 9 volts AC for emergency exciter lamp supply if the rectifier becomes inoperative. The ballast lamp is employed to maintain constant output voltage with a plus or minus variation of 10% in line voltage. The exciter lamp is controlled by the "REC"—"AC" switch on the unit.

The unit is intended for operation on 100-130 volts AC., 50-60 cycles. Power consumption is 250 watts.

The PU-1000 unit should be installed in the AM-2033 Cabinet in the location shown on the system conduit layout drawings. External connections to the terminal strips should be made in accordance with system wiring diagram.

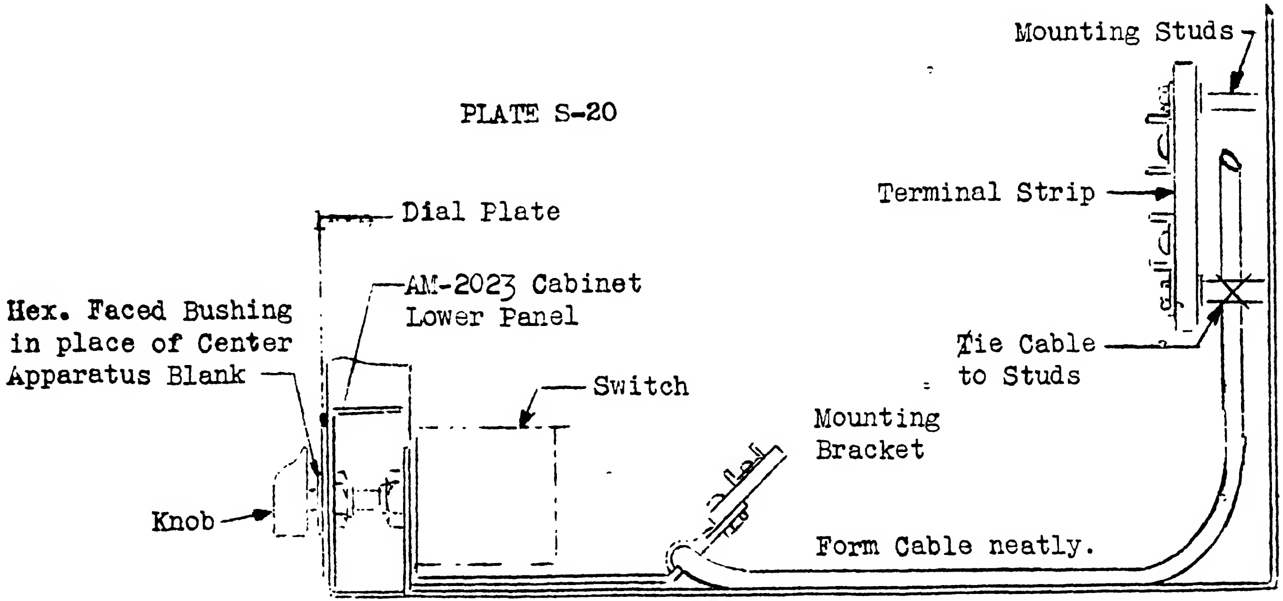
The three wires to the AM-101 Volume Control Amplifier must be twisted tightly. Do not operate the power unit without the exciter lamps installed, as the shunt resistor in the power unit may become damaged and make replacement necessary.

OPERATION OF POWER UNIT

Set the "AC" switch in "ON" position, and set "OUTPUT" switch in the "REC" position.

The tungar bulbs should normally begin to glow as soon as the "AC" switch is set in "ON" position. If

PLATE S-20



Mounting Studs
Terminal Strip
Dial Plate
AM-2023 Cabinet
Lower Panel
Hex. Faced Bushing
in place of Center
Apparatus Blank
Tie Cable
to Studs
Switch
Mounting
Bracket
Knob
Form Cable neatly.

one of the bulbs is burned out, or hard, the other bulb will not start. If the bulb is not burned out but the difficulty is due to a "hard" tube, the "AC" switch should be operated several times, which will in most instances start the "hard" tube. Otherwise, replacement of the tubes is necessary.

EMERGENCY OPERATION OF POWER UNIT

Set "AC" switch in "ON" position and "OUTPUT" switch in "AC" position. The "OUTPUT" switch in this position disconnects the rectifier transformer, and the tungar bulbs are dark.

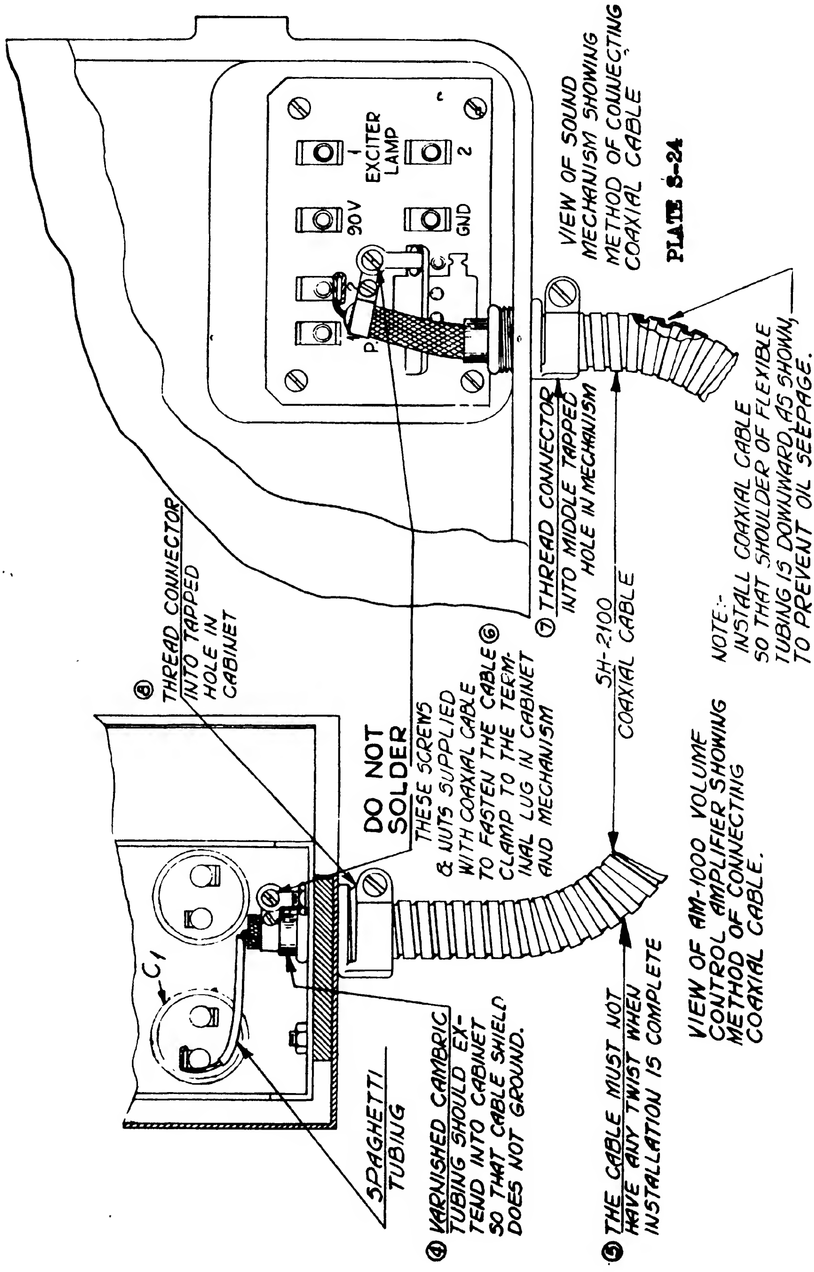
MAINTENANCE OF POWER UNIT

Check the Tungar Bulbs periodically to make sure that the bulbs are tight in their sockets, and that the springs make good contact. Loose bulbs will cause heating of the springs and crystallization, followed by spring breakage. A burned out bulb should be replaced at once as the other bulb will not carry the load. Flickering of the pilot light in the AM-101 Volume Control Amplifier is an indication of a defective bulb.

The prongs of the ballast lamp should make good contact, and the prongs and socket contacts should be clean and bright. Check these periodically. Careful bending of the socket contacts and burnishing of prongs and contacts with crocus cloth may be resorted to if necessary.

Check all clamping rings and nuts of condensers periodically, and tighten if necessary.

The Exciter Lamp current should be checked periodically by the method already described. If an ammeter is not available, a DC Voltmeter may be connected across the exciter lamp terminals "1" and "2" in the "ON" sound mechanism. The meter should read 8.5 volts minimum, 9.0 volts maximum. If the voltage is lower, readjust. If readjustment is impossible, replace ballast lamp and tungar bulbs successively, and repeat adjustments.



8 THREAD CONNECTOR INTO TAPPED HOLE IN CABINET
DO NOT SOLDER
THESE SCREWS & NUTS SUPPLIED WITH COAXIAL CABLE TO FASTEN THE CABLE 6 CLAMP TO THE TERMINAL LUG IN CABINET AND MECHANISM
SH-2100 COAXIAL CABLE
NOTE:- INSTALL COAXIAL CABLE SO THAT SHOULDER OF FLEXIBLE TUBING IS DOWNWARD, AS SHOWN, TO PREVENT OIL SEEPAGE.
7 THREAD CONNECTOR INTO MIDDLE TAPPED HOLE IN MECHANISM
EXCITER LAMP
1
2
90V
GND
P
VIEW OF SOUND MECHANISM SHOWING METHOD OF CONNECTING COAXIAL CABLE
C_1
SPAGHETTI TUBING
4 VARNISHED CAMBRIC TUBING SHOULD EXTEND INTO CABINET SO THAT CABLE SHIELD DOES NOT GROUND.
5 THE CABLE MUST NOT HAVE ANY TWIST WHEN INSTALLATION IS COMPLETE
VIEW OF AM-1000 VOLUME CONTROL AMPLIFIER SHOWING METHOD OF CONNECTING COAXIAL CABLE.

PLATE S-24

PU-1000 POWER UNIT

This is an all AC operated, chassis type power unit, weighing 42 lbs. Two terminal strips on extension cable forms are provided for external connections. It consists of a full wave rectifier, using two or four 5Z3 vacuum tubes. This unit supplies a maximum of 0.75 ampere at 220 volts DC, to energize the fields of two to six stage speakers.

The power unit should be installed in the AM-2023 Cabinet. External connections to the terminal strips should be made in accordance with the system wiring diagram. To operate, set the "AC" switch in the "ON" position. Vacuum tubes should begin to warm up immediately. For maintenance follow instructions given for PU-1000 Power Unit.

SIMPLEX AM-2013 SWITCH

This switch is supplied when two or more AM-1001 Amplifiers operate in parallel, it is a three-position amplifier selector switch assembled on a bracket, and provided with cables for equipment inter-connections and a terminal strip for external connections.

In the mid-position all system amplifiers operate in parallel. In the left position Amplifiers No. 1 operate, and Amplifiers No. 2 are disconnected. In the right position amplifiers No. 2 operate, and amplifiers No. 1 are disconnected. Inoperative amplifiers output, (external heater and plate circuits and "warping" circuit), may therefore be disconnected, and the system operated on the remaining amplifiers. Only one warping circuit is used at a time. The input is not disconnected in order that the inoperative amplifiers may be tested and serviced while the system is in operation.

INSTALLATION OF SWITCH

The switch should be installed in the bottom of the AM-2023 Cabinet in place of the center apparatus blank as per Plate S-20, and connections made in accordance with the wiring diagram.

The shields of the five shielded wires are bound

together at the switch, but are not grounded. To avoid loop grounds and noise, the shields should be grounded, during installation only at the amplifier to which the cold water pipe ground wire is connected.

SIMPLEX VOLUME CONTROL CABINETS

The AM-101 is a wall mounting cabinet, it contains an AM-1000 Volume Control Amplifier, a sound and exciter lamp changeover switch, and a pilot lamp. The cabinet is surface mounted for exposed conduit installation, and may be partially recessed in the wall when the conduit is concealed.

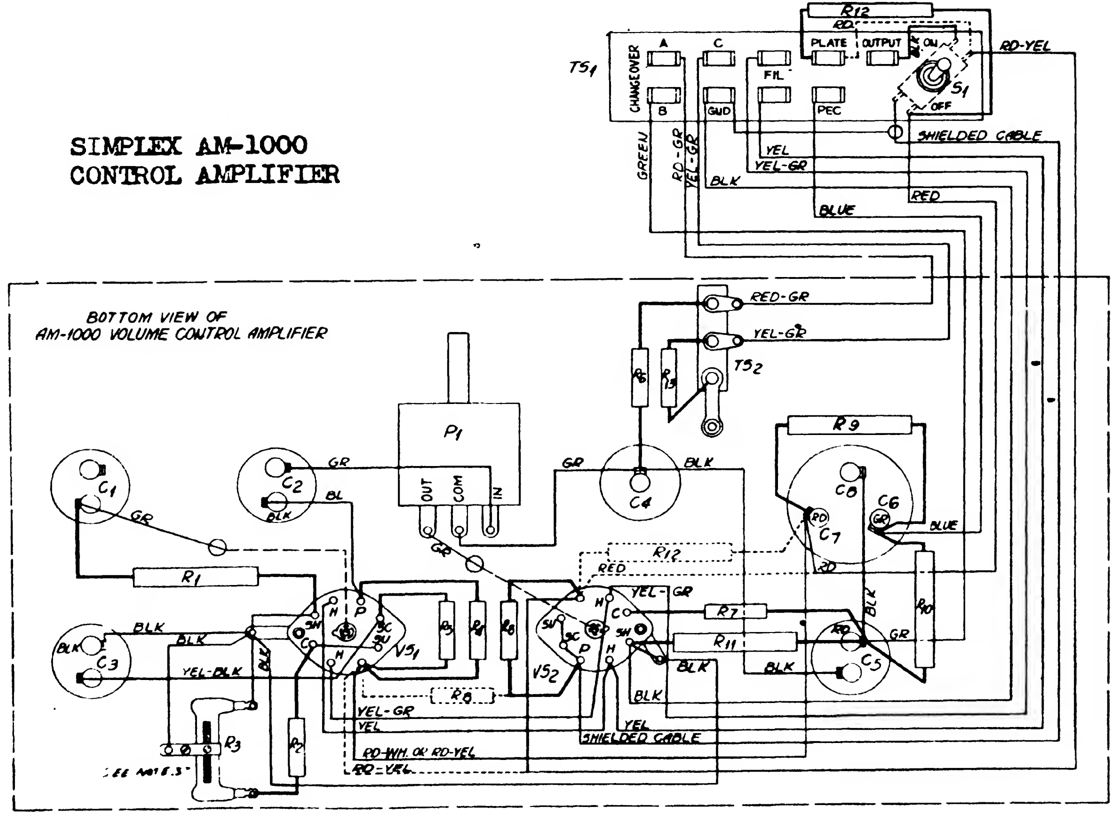
The AM-1000 Volume Control Amplifier is a two-stage, resistance coupled, inverse feed-back amplifier using two 6J7 tubes. The tube having the "X" mark on the bottom of the base is specially selected for low noise level, and should be installed in the first stage (VT1), Plate and filament supply are obtained from the power amplifier, and a voltage divider in the AM-1000 provides Photocell polarizing potential.

Changeover is made at either projector by depressing the switch button on the front of either cabinet, sound and exciter lamp being transferred at the same time. The circuit used is of the three-way type. An electronic type of sound changeover is employed. In the "ON" amplifier the second tube has normal bias, whereas in the "OFF" amplifier the bias of this tube is increased beyond cut-off and the amplifier is inoperative. There is no switching in the sound circuit, and the changeover is instantaneous and noiseless.

The exciter lamp changeover provides for preheating of the stand-by lamp on AC to eliminate thermal lag in the filament. The pilot lamp indicates the machine in use.

One AM-101 should be mounted below each observation port at such a height that the 1" conduit between the two cabinets is below the projection port. Since a fixed length of SH-2100 Coaxial Cable, Plate S-24, is shipped with the system for coupling between

SIMPLEX AM-1000
CONTROL AMPLIFIER



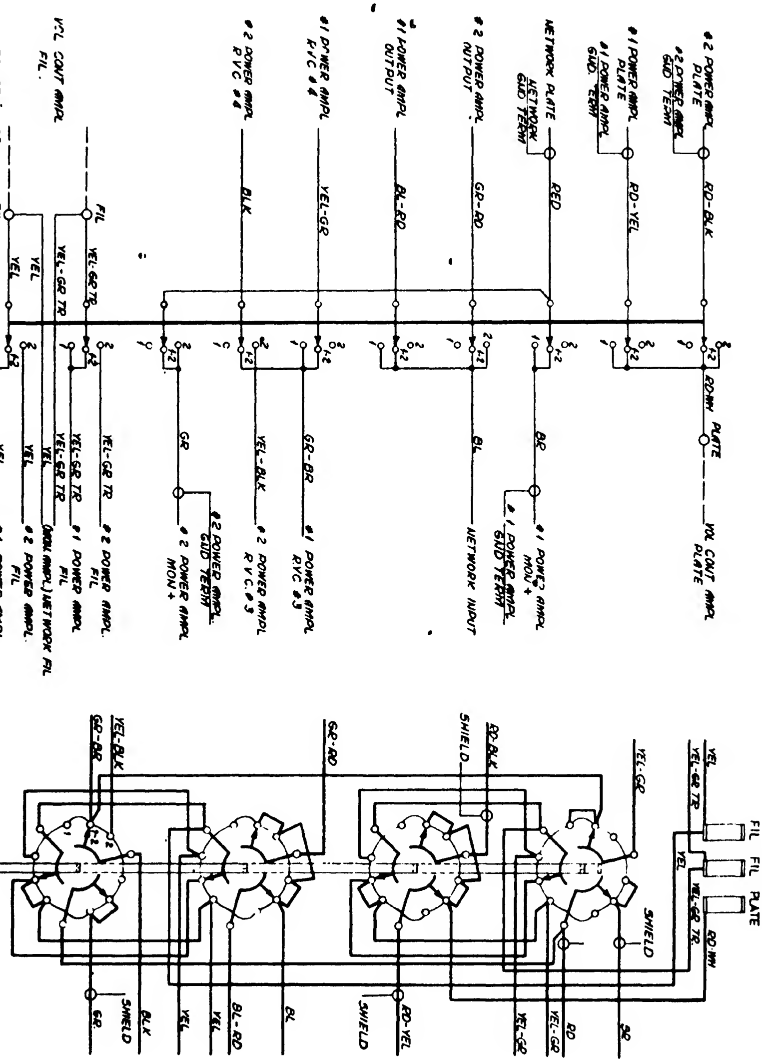

#2 POWER AMPL PLATE
#2 POWER AMPL GUD TERM
#1 POWER AMPL PLATE
#1 POWER AMPL GUD. TERM
NETWORK PLATE
NETWORK GUD TERM
#2 POWER AMPL OUTPUT
#1 POWER AMPL OUTPUT
#1 POWER AMPL R.V.C. #4
#2 POWER AMPL R.V.C #4
VOL CONT AMPL FIL.
RD-BLK
RD-YEL
RED
GR-RD
BL-RD
YEL-GR
BLK
FIL
YEL
YEL-GR TR
RD-WH PLATE
VOL CONT AMPL PLATE
#1 POWER AMPL MON +
#1 POWER AMPL GUD TERM
NETWORK INPUT
#1 POWER AMPL R.V.C #3
#2 POWER AMPL R.V.C. #3
#2 POWER AMPL GUD TERM
#2 POWER AMPL MON +
#2 POWER AMPL FIL
#1 POWER AMPL FIL
(VOL AMPL) NETWORK FIL
GR
BL
BR
GR-BR
YEL-BLK
SHIELD
FIL FIL PLATE

PLATE 8-21

the photocell output and the AM-101 input, it is essential that the volume control amplifier be so located that the coaxial cable can be properly installed and connected. The connections to the terminal strips should be made per the system wiring diagram. Plate S-24.

All wires connected to terminals in the cabinet should run below the terminal strips and not above, to avoid possible interference between these wires and the AM-1000 chassis.

The microphone cable, connected to the output terminal, should be securely fastened, by means of cord through tie cord holes in the terminal strip, in such a manner that there is no strain on the conductor.

EQUALIZATION OF PHOTOCELL OUTPUTS

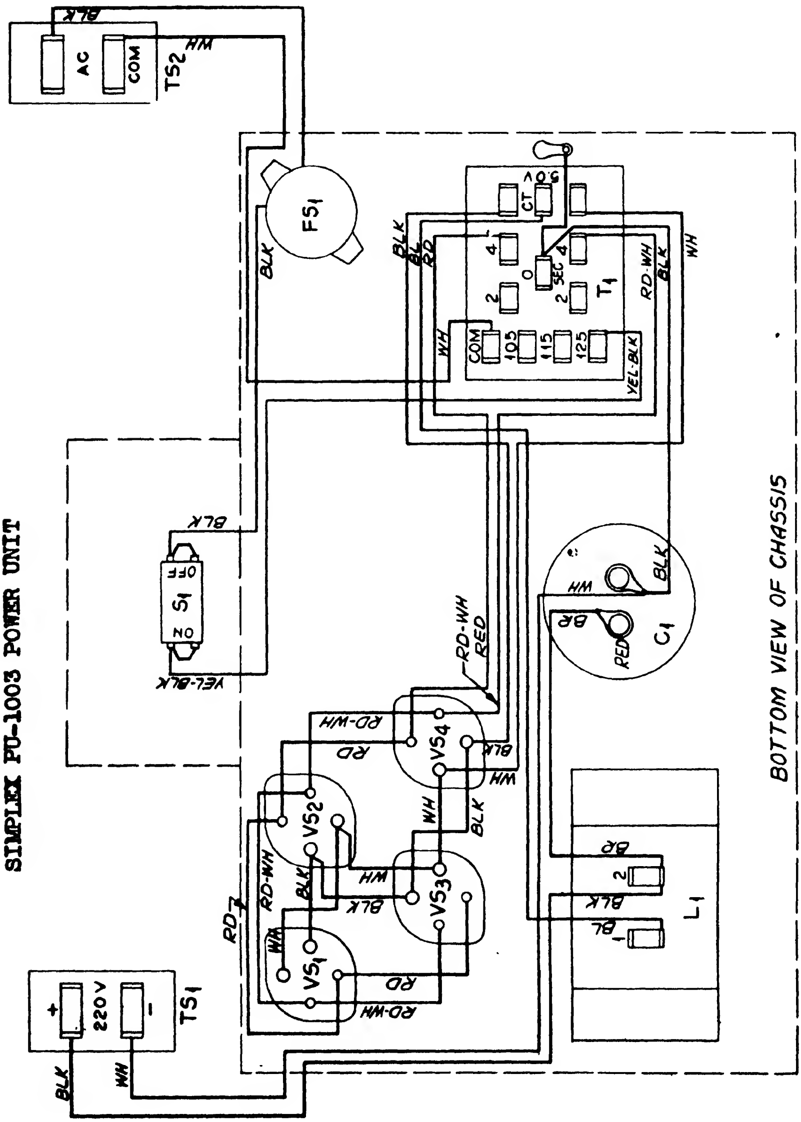
The resistor R3 should be adjusted so that the output of all volume control amplifiers is the same, with the same setting of the main volume control. This resistor should be adjusted after all adjustments have been made in the sound mechanism, and when carefully made will accurately equalize outputs.

The main volume control should be adjusted as required to compensate for the variations in prints, size of audience, etc. In establishing normal operating level initially for a specific theater, set the volume control on step 9, run a standard recording, such as the Academy Test Reel, and adjust the gain control in the power amplifier as required to obtain adequate volume control level in the theater auditorium.

OPERATION AND MAINTENANCE

Set the switch on the terminal strip of the amplifier in "ON" position, and the changeover switch so that the projector being threaded is inoperative (pilot lamp is out). Changeover is then made, when the incoming machine is up to proper speed, by depressing the switch button on either cabinet.

If the pilot lamp does not light, check the fuse mounted on the terminal strip mounting bracket, as removal of the exciter lamp while the power unit is



SIMPLEX PU-1003 POWER UNIT

in operation may cause the fuse to blow. Otherwise the pilot lamp should be replaced by removing the socket from the inside of, the cabinet. Maintenance of tubes and tungar bulbs has already been covered in this book.

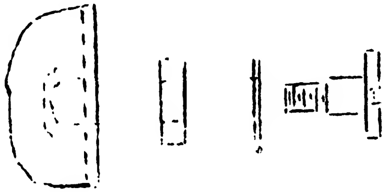


PLATE S-26

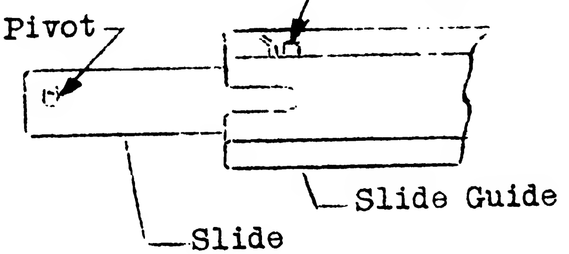
Special Screw

SIMPLEX AM-2023 CABINET

This is a ventilated metal cabinet, it is surface mounted on the wall for exposed conduit installations, and may be partially recessed in the wall when the conduit is concealed. The cabinet has a removable front cover, and any three of the standard chassis units (power amplifier, loudspeaker network or power unit) may be installed in it.

Each chassis unit is mounted in the cabinet on pivoted slides so that it may be partially withdrawn,

PLATE S-27

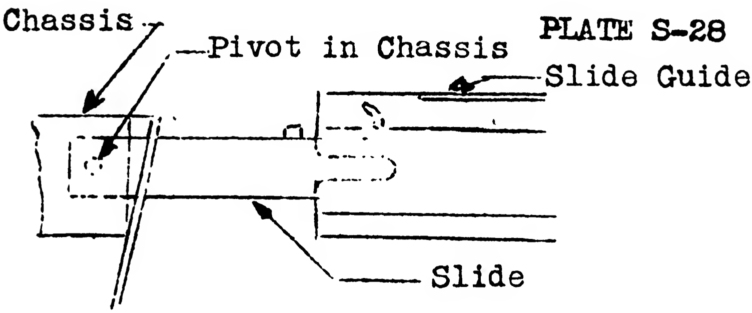


like a drawer is pulled out, and then rotated 180 degrees. A trigger pin on each slide limits the forward travel of the unit, and it cannot be rotated until the

limit of travel has been reached. All equipment above and below the chassis is accessible for inspection and test without removal of the unit from the cabinet.

One to three selector switches for amplifier selection or similar use, may be mounted behind the bottom panel upon removal of the apparatus blanks.

PLATE S-28



INSTALLATION

Each unit should be installed in the cabinet in the location shown on the system conduit layout drawing. The selector switch should be installed first. Each unit beginning at the bottom of the cabinet, should be installed as follows:—

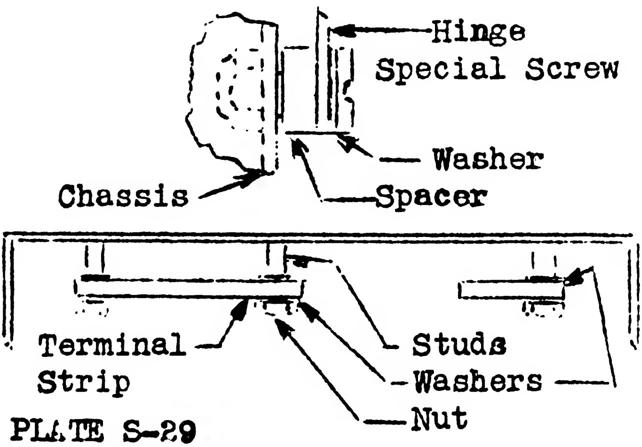
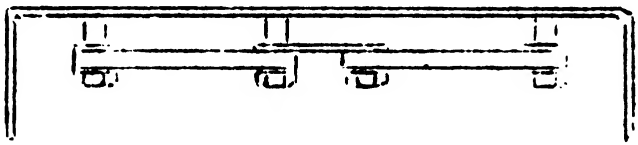


PLATE S-29

Remove the two special screws from the chassis, Plate S-26. These screws fasten the hinge to the chassis.

Remove the associated left and right slides from the cabinet by depressing the slide trigger pin (visible



LU-1026 Network Only
PLATE S-30

in rectangular opening on top of guide assembly) Plate S-27, until the slide releases. The slides are lubricated with grease during manufacture, but should be given a light coating of vaseline if necessary.

Invert the unit, Plate S-28, and with its panel toward the cabinet insert the pivot on each slide in the

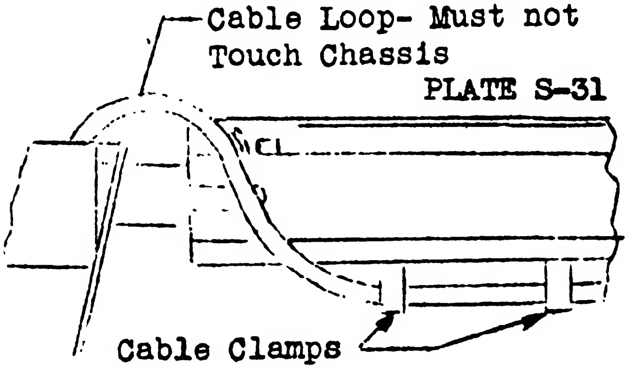


PLATE S-31

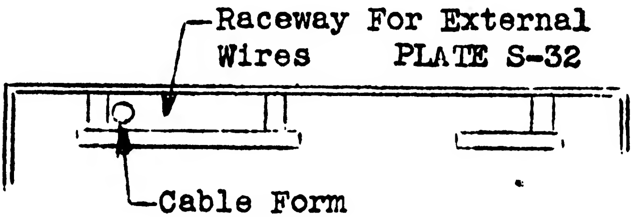
pivot holes on the chassis (trigger side up), place the slides in the guides in the cabinet, depress the trigger pin to slide under the front edge of the guides, and push the assembly until the slides lock.

Attach the hinges to the chassis using the two special screws already removed. See Plate S-29.

Mount the terminal strips on the studs on the back of the cabinet, just above the unit installed, with the fibre spacers under the strip, a washer above and below the strip, and the nuts above. Plate S-30.

The cable forms should be installed so that they have a natural tendency to lead toward the side of the cabinet, thus being out of the path of the chassis below when it is rotated. Avoid twisting the cables.

Insert the cable forms in the cable clamps beneath the guides, and form neatly. The cable at the chassis end should be formed in a loop to clear the edge of the chassis when it is in its inverted position. Some of the cables are reinforced to indicate their normal position with respect to the cable clamps. Plate S-31.



Make all external connections to the terminal strips as per system wiring diagram. All inter-connecting and external wiring should be routed behind the terminal strips in the raceway formed by the terminal strip mounting studs and beneath the cable form to facilitate removal of the unit. Plate S-32.

Rotate the unit to normal position, slide into the cabinet, and proceeds with the assembly of the next unit.

Due to the light weight of the network, it may be necessary to put a slight pressure on the top of the chassis to depress the trigger sufficiently to release the unit so that it may slide into the cabinet.

SIMPLEX "TYPE A" SYSTEM

To start the system turn "AC" switches on the AM-1001 Amplifier and the PU-1000 Power Unit to "NO" position. If a master power switch is provided in the main power supply, these "AC" switches may be left in the "ON" position and the AC power controlled by the master switch.

If the main power supply is DC, the rotary converter should be started before the AC switches are thrown.

Be sure the switch on each amplifier is set on the "NO" position. Check the change-over switch during the sound test by changing over at each position twice.

For a preliminery sound test, move a small card rapidly in and out of the light beam between the reflector lens and the photo-electric cell in each mechanism. A "thump" should be heard from the stage and monitor speakers. If possible a short reel should be run in each projector to test for sound quality and to test stage speakers.

Be sure the lateral guide is closed after film is threaded. If mechanism door will not close, the lateral guide is open. Pull the lateral guide roller assembly outward, after threading is completed, until it is in firm contact with the knurled adjusting nut.

Turn the power switch on the motor to "ON" and when the motor is up to proper speed make the sound change-over. To make the change-over, operate the change-over switch in either volume control amplifier.

INSTALLATION

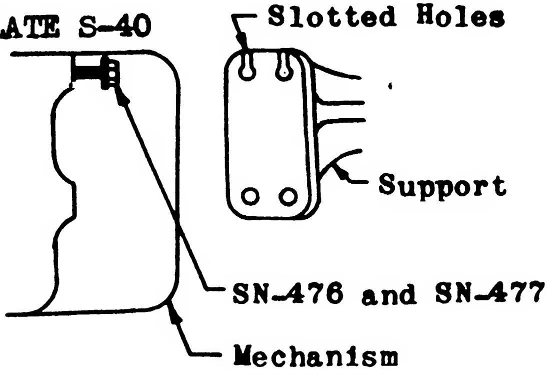
Remove all existing equipment from projector pedestal and install the soundhead supports supplied with system, after cleaning all parts install as follows:

The main frame assembly is bolted to the soundhead support with four hex head bolts and washers. Insert two upper bolts, hang assembly in slotted holes, and then thread in the two lower bolts.

Remove the motor, motor switch and flywheel guard from the bracket, and mount the bracket on the front

of the sound machanism. Mount the motor, motor switch and flywheel guard. The motor slides into the flexible coupling on the drive gear box shaft, the motor is positioned laterally so that it lines up with the coupling. Slotted holes are provided in the motor base and clearance holes in the motor bracket for alignment purposes.

PLATE S-40



Bolt the lower magazine and cable clamp bracket to the bottom of the sound mechanism.

To install the projector mechanism, remove the blue guard, on the non-operating side, and the bar on the top of the mechanism as a unit, by taking out the screw on the side of the mechanism and the two bolts fastening the bar to the machanism.

Detach the blue guard from bar, as this guard is provided only as a protection in shipment. Fasten the oil shield and bar to the mechanism, the part marked "F" on bar should be at front. Mount the projector mechanism oil shield and bar assembly on the sound mechanism. Install the drive gear and stud supplied with the system, turning the adjusting screw on the front of the mechanism so that proper mesh is obtained between the drive and driven gears. Now bolt the upper magazine to top of projector mechanism.

The coaxial cable should be installed in accordance with instructions which come with the equipment, the

flexible conduit from the volume control amplifier and the drive motor power supply, should be connected as per wiring diagram.

To install the damping wheel, remove the screw and nut from the drum shaft on the non-operating side, the two loose spring washers on the shaft should not be

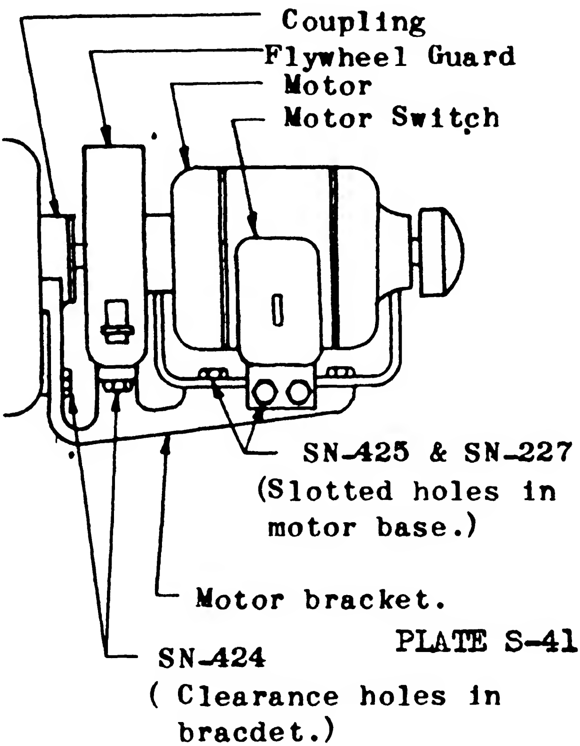


PLATE S-41

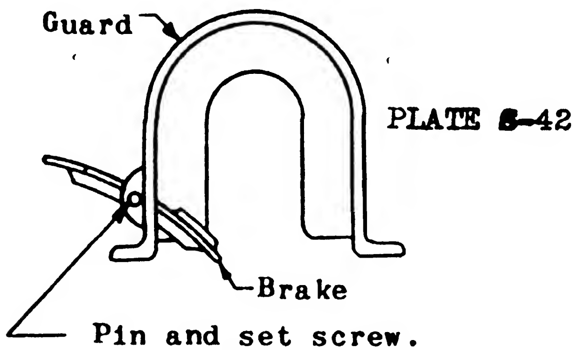
removed. Slide the damping wheel carefully onto the shaft while holding the scanner drum H on the operating side, against its shoulder. Now line up the mounting holes in the shaft and wheel, and screw into position.

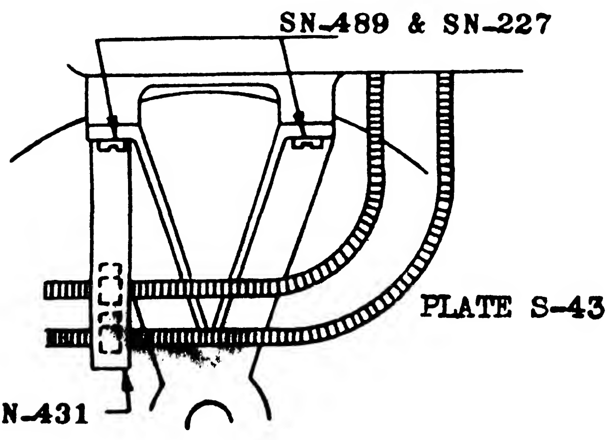
Push the stabilizer drum carefully toward the operating side as far as it will go, and release it. If the drum does not return and seat itself firmly against its

shoulder, there is too much end play. To cure the end play, the damping wheel should be removed and one of the washers removed.

Attach the rear guard to the non-operating side of the main frame assembly.

Install the exciter lamp and the photo-electric cell, then fill the gear box on the non-operating side slowly with oil to the red line on the sight glass.





ADJUSTMENT OF THE SCANNER SYSTEM

The main frame assembly is shipped with the exciter lamp bracket, lens tube and reflector lens mount-

ed and adjusted ready for use. It is recommended however, that the adjustments be checked, using a 9,000 cycle film and volume indicator to make sure that maximum response is obtained.

The adjustment procedure for each of the units is given below.

Due to the use of a pre-focused base exciter lamp, only a vertical and lateral adjustment are provided. For vertical adjustment loosen the clamping screw on the left of the bracket and adjust knurled screw at bottom as required. For lateral adjustment, a screw

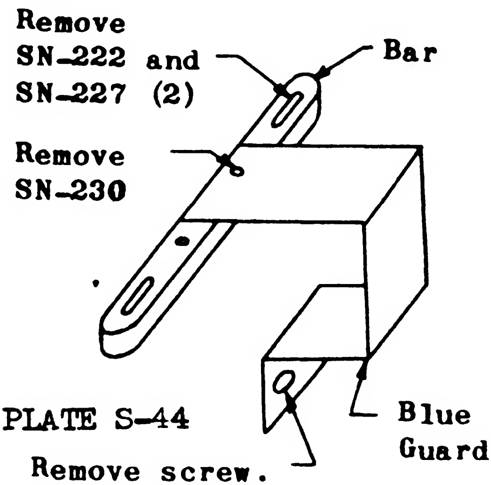


PLATE S-44

and lock nut are provided on the front of the bracket. To move the bracket inward loosen the screw, to move the bracket outward, tighten the screw.

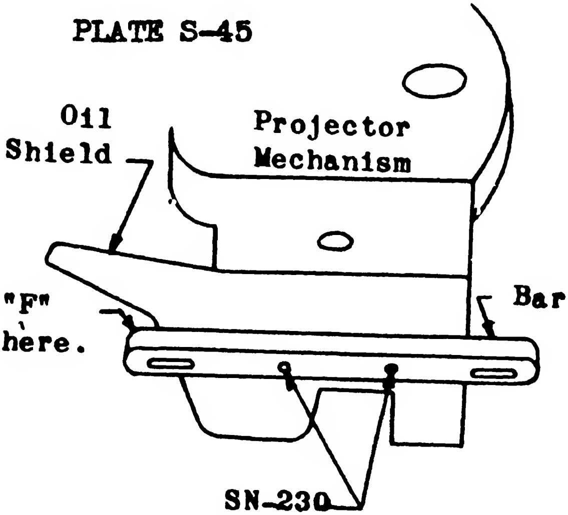
Maximum response is obtained when the filament of the exciter lamp is exactly centered on the tube lens slit. To focus the lens tube loosen the clamping screw above the lens barrel, and turn the knurled adjusting screw as required. Two methods of adjustment may be used, the response test or the flicker test.

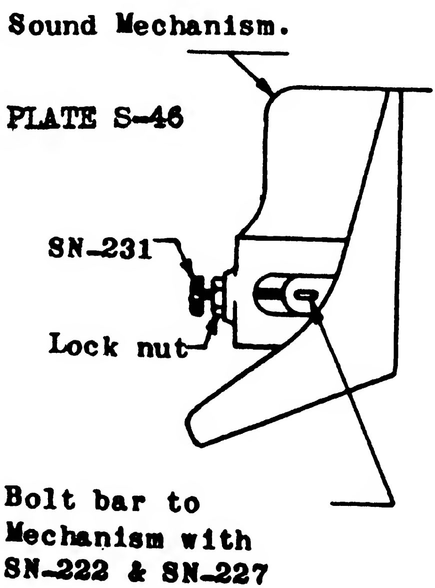
RESPONSE TEST

Thread the projector with a 9,000 cycle test film,

run the projector, and adjust the lens tube for focus until maximum response is obtained on a volume indicator or aurally.

PLATE S-45



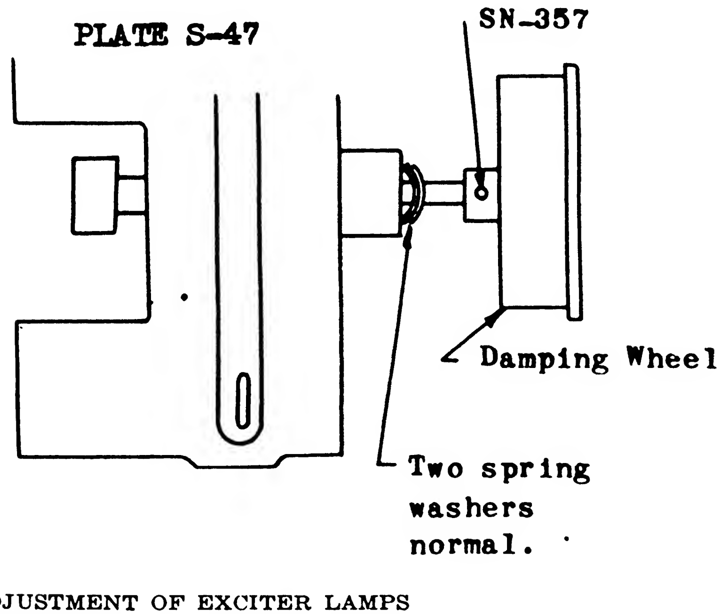


FLICKER TEST

Thread the projector with a 9,000 cycle film, place a white card between the film and the reflector lens, and turn the motor slowly by hand. The film frequency lines make a definite flicker of light on the card.

The tube is focused when the lines are stationary. If they move downward on the card, the lens tube should be closer to the film. While if they move upward, the tube should be further from the film.

PLATE S-47



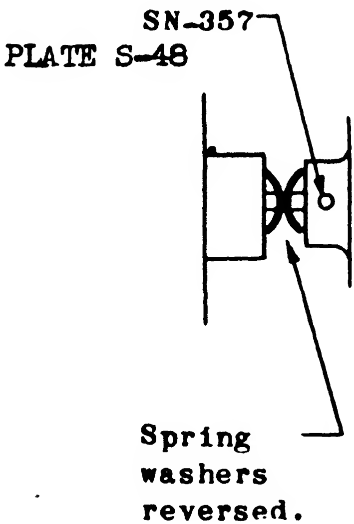
ADJUSTMENT OF EXCITER LAMPS

It is important that the adjustments to obtain 4 ampere DC exciter lamp current be made carefully. The ballast lamp has a definite operating range, and the lamp should operate within the limits of this range. If the exciter lamp current is low, response and output are affected. If the current is too high, the life of the lamp is materially shortened.

Be sure that the transformer primaries are connected for the average line voltage during operating

hours, that proper connections are made. Be sure that the shunt and rheostats on the front are in extreme counter-clockwise position.

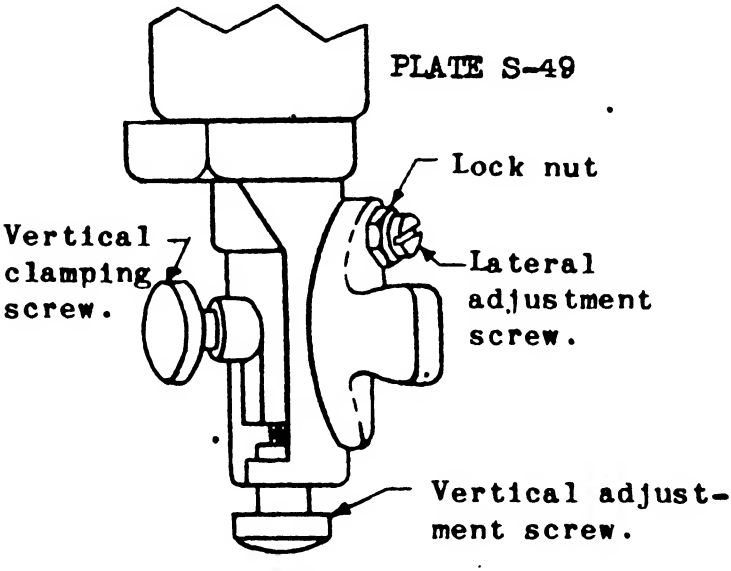
In the rear left corner remove the metal strap at "A" and connect a DC Ammeter (0-10 scale) to the two terminals. Connect a DC Voltmeter (0-15 scale) to the two terminals in the rear left corner marked "V". Set the AC switch in the "ON" position, the "OUTPUT" switch in the "REC" position, and allow the ballast lamp to heat up. Now adjust the series rheostat until the current reads 4 amperes, adjust the shunt rheostat so the voltage across the ballast lamp reads 10 volts.



Re-adjust the series and shunt rheostats successively as required to obtain the above ratings, as the adjustment of one affects the other. A minimum of ten seconds should be allowed between adjustments to permit stabilization of the ballast lamp.

If the voltage across the ballast lamp, with rheostats in extreme counter-clockwise position, is more than 10 volts, transfer the "low" leads from tap "3" to tap "2" or tap "1" as required, before making the

adjustments above. On the other hand, if the rheostats are near the extreme clockwise position before a balance is obtained, transfer the "low" leads from tap "3" to tap "4". The current must be adjusted to 4 amperes. The voltage across the ballast lamp may be min. 9.5 and max 10.5 volts if closer adjustment is not possible.



EXCITER LAMP AC

To adjust the AC exciter lamp supply, set the "OUTPUT" switch in the "AC" position, connect an AC Voltmeter (0.15) across "COM' and "DC" terminals in the rear left corner, and adjust "AC" rheostat until the meter reads 9 volts. Also check the "preheat" voltage (2 volts AC) by connecting the voltmeter terminals across "AC" and "COM."

SIMPLEX SOUND HEAD

The SH-1000 is a film propulsion mechanism for the reproduction of sound from 35 mm sound film by the photocell method. It reproduces from single track

sound film, or from either single track or push-pull sound film if equipped with the special Push-Pull kit.

THE MECHANISM

The mechanism is attached to the sound head sup-

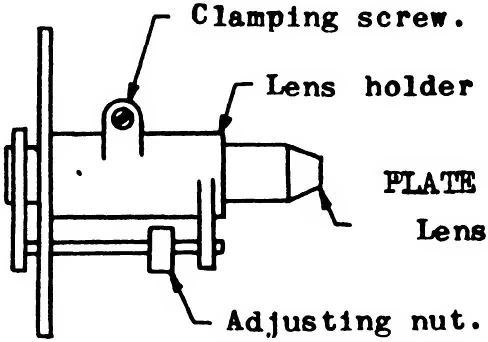


PLATE S-50

port arm, mounted on the projector pedestal. The motor assembly, including a motor and flywheel, flywheel guard and hand-brake on a bracket, is attached to the front of the sound mechanism, and drives the pro-

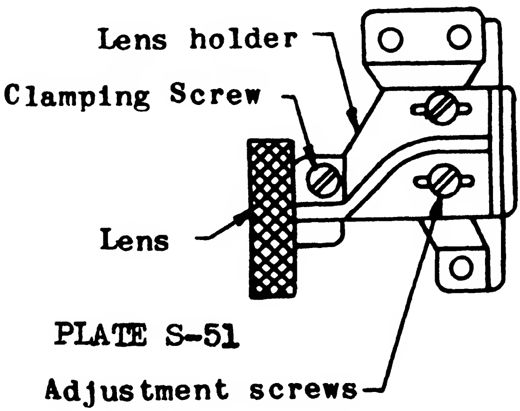


PLATE S-51

jector and the constant speed sound and holdback sprockets in the mechanism through a reduction gear box. The gear box may be removed as a unit. The hand-brake, which engages the flywheel, is provided

to stop the mechanism in case of film breakage. The take-up is driven from the mechanism by belt drive, although a chain drive is also available.

SCANNING SYSTEM

This is attached to the sound mechanism by a special vibrationless mounting, it is located at the rear of the mechanism. The rotary stabilizer maintains con-

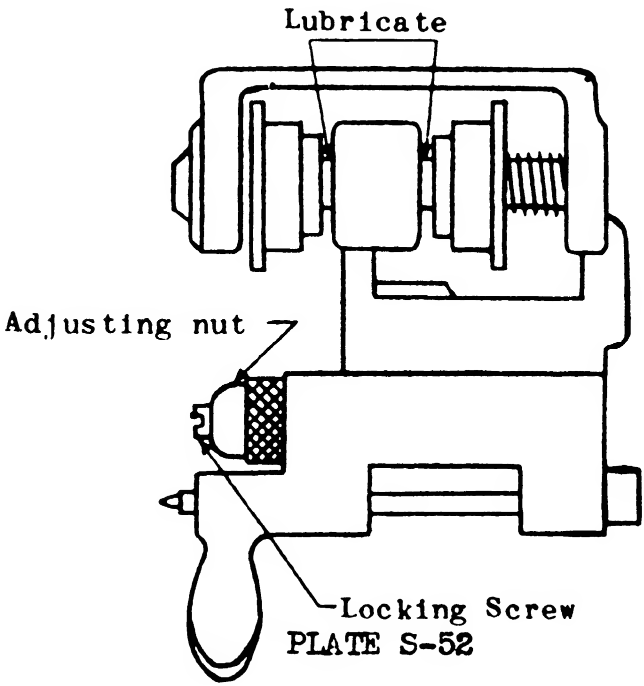


PLATE S-52

stant film speed past the scanning beam. A prefocused exciter lamp on an adjustable bracket provides an intense source of light to illuminate the slit in the optical system.

Light from the optical system passes through the film sound track, and is reflected to the photocell by an adjustable lens mirror. The vertically mounted photocell and wiring are shielded from oil leakage and static pick-up. The Photocell polarizing potential and

exciter lamp supply are obtained from separate sources.

REFLECTOR LENS—SINGLE TRACK FILM

If properly adjusted the spot on the photocell should be about 7/16" in diameter and centered on the anode of the cell. To position the spot of light, loosen the clamping screw at the top of the lens holder (Plate S-50) and carefully rotate the lens until the

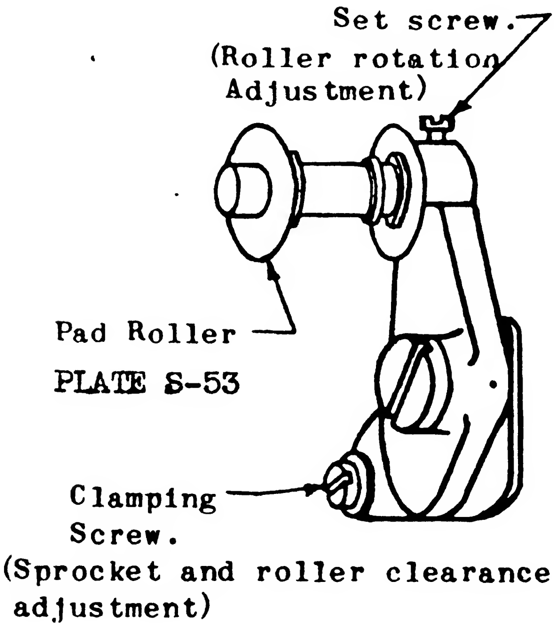


PLATE S-53

spot is centered on the anode. To change the size of the spot, move lens in or out of the bracket as required. If further movement is required, loosen the two lens holder mounting screws and adjust as necessary. Slotted holes are provided in the lens holder.

These adjustments are more readily made if the photo-electric cell is removed and a piece of transparent paper substituted. A still more convenient method is to remove the glass envelope and cathode from an old photocell, and substitute a transparent

paper cathode attached to the cathode support wires. With either of these methods the spot can be accurately centered and adjusted for size.

PRESSURE AND GUIDE ROLLER

To adjust, loosen the locking screw in the center of the knurled adjusting nut and turn the nut as required, Plate S-52. Clockwise rotation moves the roller inward. Be sure that the spiral spring at the rear of the pressure and guide roller holds firmly against the knurled adjusting nut at all times. When properly adjusted the scanning beam does not strike the frame lines or sprocket holes. Check the adjustment, using the Academy Buzz Track Film and make final precise adjustments with Academy Standard Illumination Test Track.

PAD ROLLERS

The clearance between the sound and hold-back sprockets and their pad rollers should be equal to two thicknesses of film. To adjust, loosen the fillister head clamping screw, Plate S-53, insert two thicknesses of motion picture film between the rollers and sprocket, press the roller firmly against the film and then tighten the screw.

The rollers should rotate freely. To adjust, loosen the set screws, Plate S-53, at the top of the bracket, grasp the knurled roller stud, pull carefully until the roller rotates freely and tighten the clamping screw. Do not allow more clearance than is necessary for free rotation.

THREADING FILM IN SOUNDHEAD

Film should be threaded in the projector mechanism with the instructions given elsewhere in this book. Film should be threaded in the sound mechanism as shown in the diagram, Plate S-54.

OPERATION OF SOUND HEAD

Clean the mechanism thoroughly each day. It is extremely important that all glassware, reflector lens and lens tube lenses be thoroughly cleaned with lens

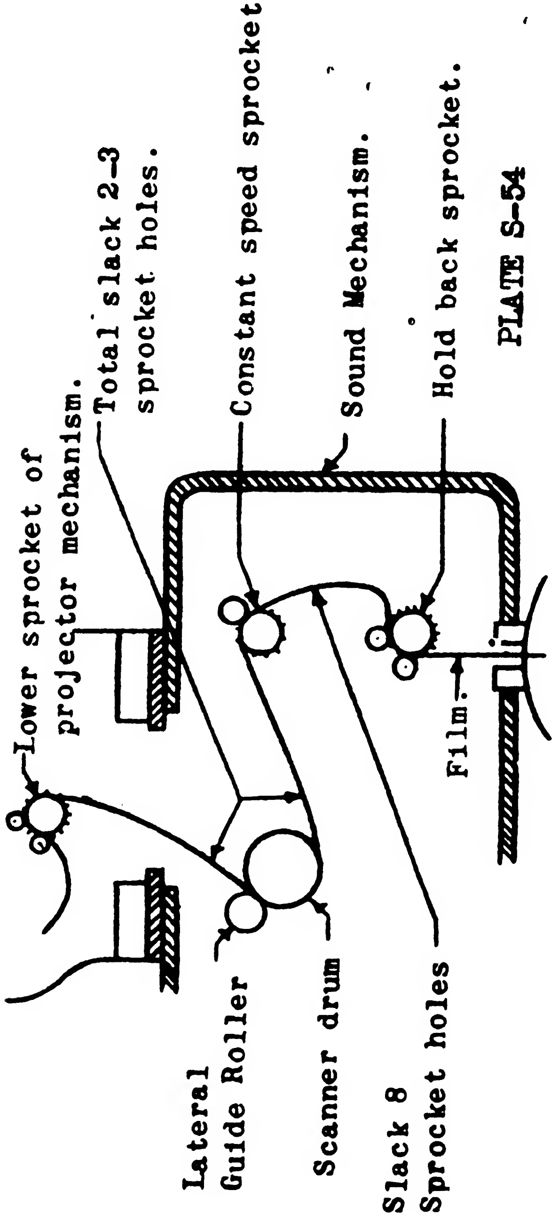

Lower sprocket of
projector mechanism.
Total slack 2—3
sprocket holes.
Constant speed sprocket
Sound Mechanism.
Hold back sprocket.
Film.
Lateral
Guide Roller
Scanner drum
Slack 8
Sprocket holes

PLATE S—54

tissue as these surfaces accumulate particles, such as carbon dust, with resulting loss in gain.

SOUND TEST

Sound should be checked daily before operating. As a preliminary sound test, move a card rapidly in and out of the light beam between the reflector lens and the photo-electric cell on each machine. A "thump"

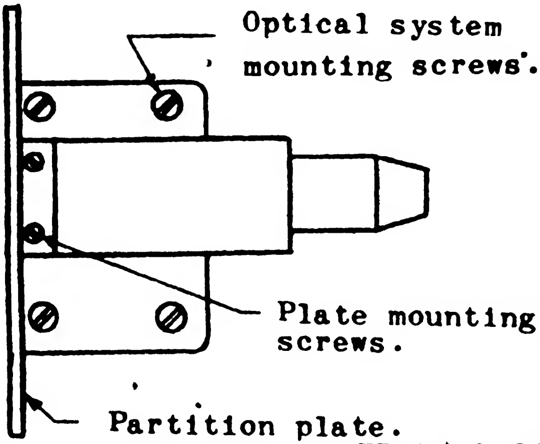


PLATE S-55

should be heard from the stage and monitor speakers. If possible a short standard reel should be run in each machine to test for sound quality and change-over.

THREADING THE MECHANISM

Thread the mechanism in accordance with the instructions already given. The lateral guide roller must be closed after threading. If the sound mechanism door does not close, the guide roller is open.

LATERAL GUIDE ROLLER ASSEMBLY

Pull the guide roller assembly outward, after threading is completed and the roller is closed, until it is in firm contact with the knurled adjusting nut.

There is a spring on the stud at the rear of the assembly to hold it firmly against the adjusting nut. In some instances, however, the assembly may be pushed inward as it is closed and may not return to its proper position due to friction. Sprocket hole noise will occur and cannot be remedied by adjustment.

If the assembly has an unusual tendency to stick, the following should improve the condition.

A drop of oil should be applied on the supporting stud between the knurled nut and the assembly. Distribute the oil along the stud by pushing the assembly back and forth and opening and closing it several times. Wipe off all excess oil.

Increase the length of the spring at the rear of the assembly from 13/16" to 1 1/8". The effectiveness of the spring will increase and will aid in returning the assembly to its proper position. To increase the length of the spring, remove the assembly and spring and stretch each spring coil carefully until the length is 1 1/8". It is essential that the lengthening be done carefully so that the ends remain perpendicular to the axis of the spring.

Leave the guide roller open when there is no film in the mechanism. If it is left closed, flat spots will develop on the felt rollers, will cause flutter and make replacement necessary.

By means of the adjusting nut locate the guide roller assembly laterally so that the scanning beam is properly positioned on the sound track, using buzz track and 17-position track film. If such film is not available, the adjustment may be made as follows:—

Thread regular release film in projector and sound mechanisms in the usual manner and start the machine.

Observe the position of the scanning beam with relation to the sound track. As an aid in observing the edges of the sound track, a flash light may be directed on the concave side of the film (that side in contact with the rotary stabilizer drum) and the image viewed from the same side of the film.

In making the above adjustments, be sure that the guide roller assembly is under tension—that is, that the spring on the mounting stud behind the guide roller assembly is in contact with the adjusting nut at all times.

While the removal and reinstallation of the optical system may not seriously affect the focus thereof, the focus should be checked with frequency film at the first opportunity.

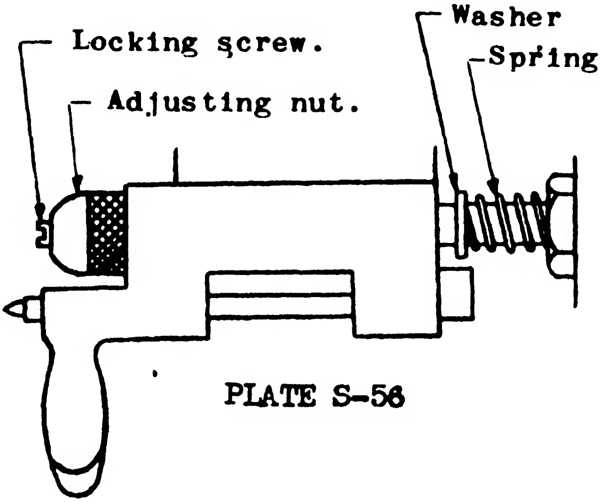


PLATE S-56

REPLACEMENT OF FELT ROLLER

Remove cover plate. Remove screw under cover plate. Use two screw drivers, one to hold screw on other end of shaft. Slide roller assembly as indicated in the sketch and remove the flange and felt roller. Install new felt roller and assemble the unit. Install the lateral guide roller assembly and adjust per the previous section.

MAINTENANCE OF SOUNDHEAD

Cleanliness cannot be emphasized too strongly. Oil, dirt and other foreign material in the mechanism will impair the quality of reproduction, increase wear and eventually cause interruptions in the show and

increase in replacements. Careful cleaning and daily inspection, on the other hand, will insure continued uninterrupted high quality sound.

EXCITER LAMP

The exciter lamp glass envelope blackens with age and the filament tends to sag. Both impair the quality and reduce the volume level. Lamps should, therefore, be inspected frequently and replaced before the condition becomes serious.

PLATE S-57

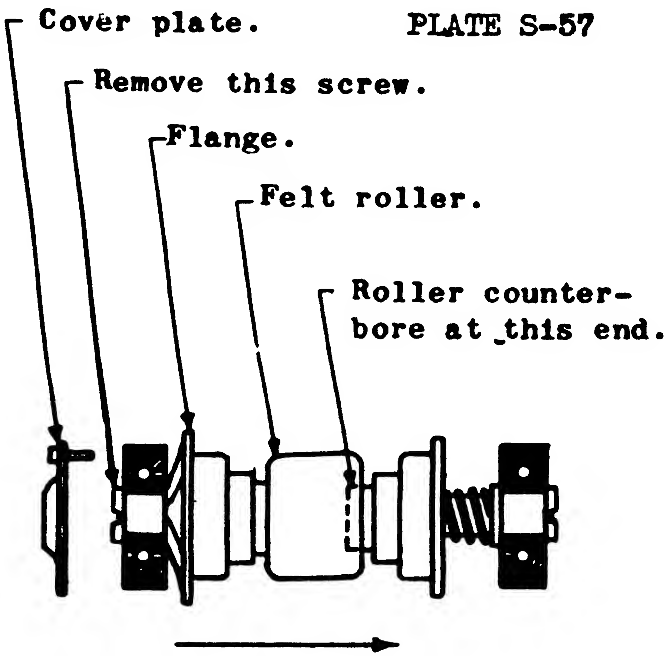


PHOTO-ELECTRIC CELL

The efficiency of the cell decreases with age resulting in a gradual decrease in output volume and frequency response. Cells should be replaced before quality is impaired.

LATERAL GUIDE ROLLER ASSEMBLY

Be sure that the guide roller is left open when there is no film in the mechanism. If left closed, flat

spots will develop on the felt rollers, will cause flutter and make replacement necessary. The guide roller assembly must be removed to replace a felt roller.

REMOVAL & REINSTALLATION OF GUIDE ROLLER ASSEMBLY

Remove the exciter lamp bracket. Remove the photo-electric cell and rear photo-electric cell shield. Remove the two screws holding the partition plate in place and slide out the partition plate. Remove the four screws mounting the entire optical system and lift out the optical system carefully. Remove the lateral guide roller assembly by first loosening the locking screw in the center of the chromium plated adjusting nut, remove the adjusting nut and slide the entire assembly from the mounting stud. Be sure that the spring and steel washer back of the lateral guide roller assembly remain on the mounting stud.

Reinstall the guide roller assembly and adjusting nut. Do not tighten the locking screw.

Reinstall the optical system, partition plate and exciter lamp bracket.

MONTHLY MAINTENANCE

Once a month inspection of the sound mechanism should be made, check for flat spots on the felt roller, as these flat spots cause flutter. The roller and flanges should rotate freely. If there is a tendency to "stick" readjust and lubricate the shaft and ball bearings. If the flanges are scored, they should be replaced.

Check the oil level in the sight guage on the non-operating side of the mechanism. Maintain the oil level so that it is just at the bottom of the glass. Oil should never be added while the mechanism is running, but only after the machine has stood idle overnight.

Check the grease cups on motor bearings, give these a half-turn, also check the Allen set screws on the motor couplings.

Test the vacuum tubes in Volume Control Ampli-

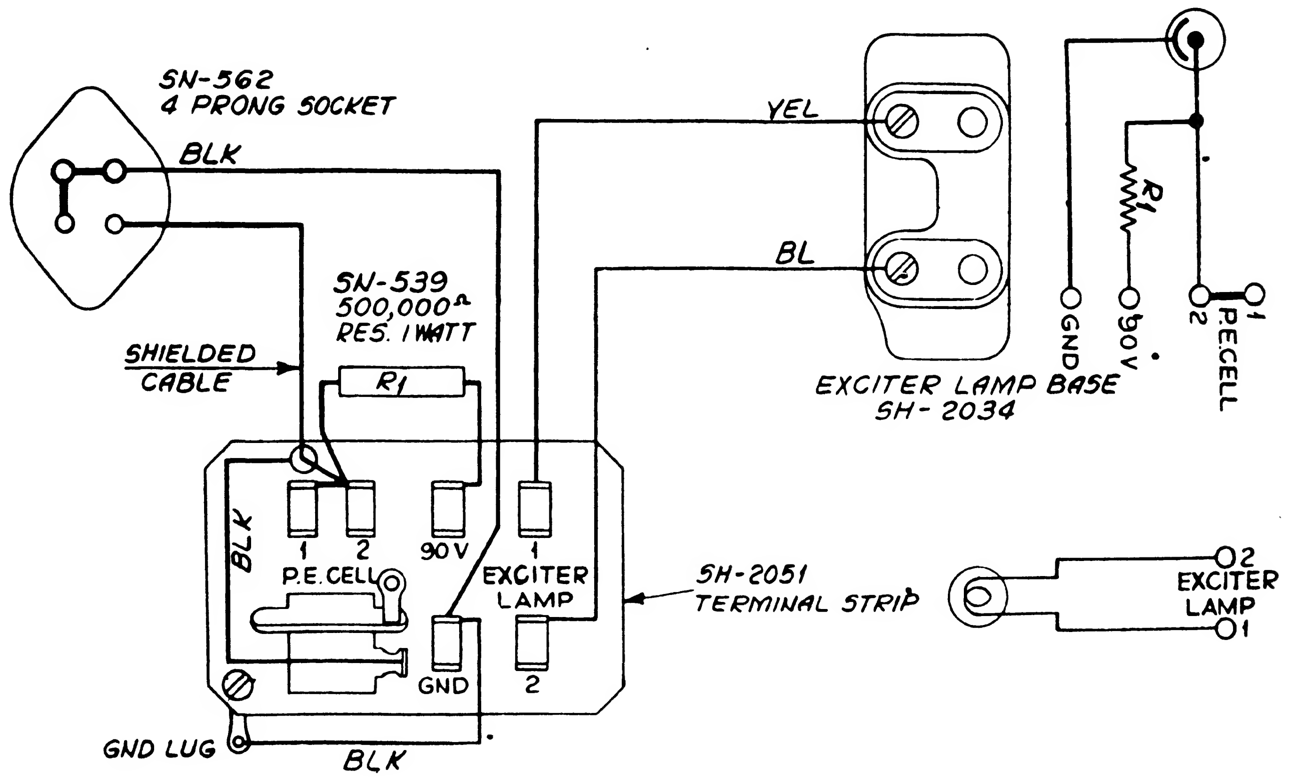
fier, by substituting a new tube, and replace the old tubes if volume and quality of sound is impaired. Remember the 6J7 tube with an "X" on the bottom should be installed in the first stage. This tube has a low noise level.

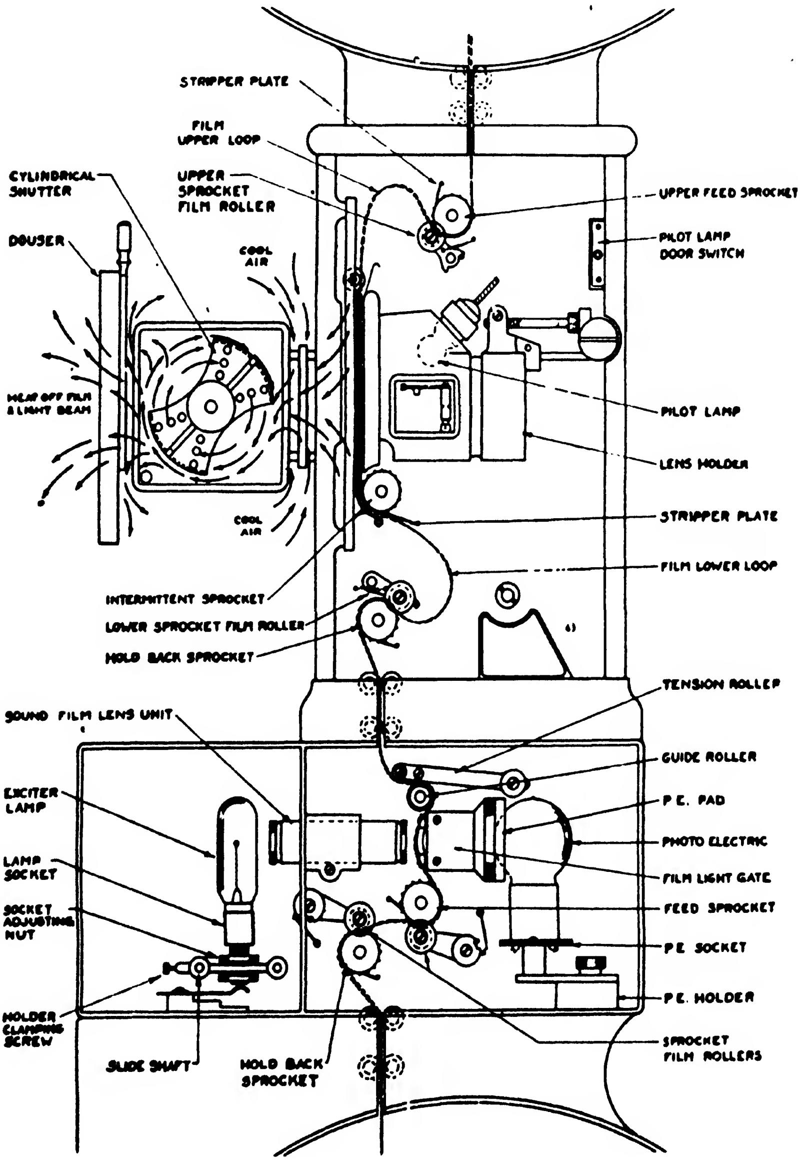
Vacuum tubes should be seated firmly in their sockets, the prongs and the socket contacts should be bright and clean, and make good electrical contact.

Check the exciter lamp current in the Power Unit. Check the Tungar Tube. The Tungar bulb should begin to glow as soon as the "AC" switch is set in "ON" position. One tube will not start if the other is burned out or "hard". A "hard" tube may, in most instances be started by operating the "AC" switch several times.

Check cover and partition screws in the monitor loudspeaker. If grille in front of speaker vibrates, insert a narrow strip of felt between left and right edges of the grille and the cabinet.

Each day apply one drop of oil to the pad rollers and the shaft of the roller assembly of the lateral guide roller with a toothpick. Check the adjustment of the exciter lamp, lens tube and reflector lens. The spot of light on the photo-cell should be 7/16" in diameter, and centered on the cathode of the cell.


SN-562
4 PRONG SOCKET
BLK
SN-539
500,000Ω
RES. 1 WATT
SHIELDED
CABLE
R1
BLK
1
2
P.E. CELL
90 V
GND
1
EXCITER
LAMP
2
GND LUG
BLK
YEL
BL
EXCITER LAMP BASE
SH-2034
R1
GND
90 V
2
1
P.E.CELL
SH-2051
TERMINAL STRIP
2
EXCITER
LAMP
1


STRIPPER PLATE
FILM UPPER LOOP
CYLINDRICAL SHUTTER
UPPER SPROCKET FILM ROLLER
UPPER FEED SPROCKET
DOUSER
PILOT LAMP DOOR SWITCH
COOL AIR
HEAT OFF FILM & LIGHT BEAM
PILOT LAMP
LENS HOLDER
COOL AIR
STRIPPER PLATE
FILM LOWER LOOP
INTERMITTENT SPROCKET
LOWER SPROCKET FILM ROLLER
HOLD BACK SPROCKET
TENSION ROLLER
SOUND FILM LENS UNIT
GUIDE ROLLER
EXCITER LAMP
P.E. PAD
PHOTO ELECTRIC
LAMP SOCKET
FILM LIGHT GATE
SOCKET ADJUSTING NUT
FEED SPROCKET
P.E. SOCKET
HOLDER CLAMPING SCREW
P.E. HOLDER
SLIDE SHAFT
HOLD BACK SPROCKET
SPROCKET FILM ROLLERS

MOTIOGRAPH MECHANISM ADJUSTMENTS

THE double bearing movement may be removed from the mechanism complete as a unit. To accomplish this, first open the film gate to free the intermittent sprocket shoe from the sprocket. This is important as otherwise the sprocket will be damaged in the removal. Remove the large door from the take-up side of the mechanism. Next it is necessary to remove the large main gear. This gear is locked to the crank shaft by a retaining screw. Back this screw off a few turns with a screw driver and by hitting the end of the screw driver with the palm of the hand sharply the screw will free the crank shaft from the gear. Now remove the retaining screw completely and draw the crank shaft free of the gear. The gear itself may now be removed by grasping its lower portion with the fingers and drawing it toward you, gently rocking the gripping disc unit at the same time to facilitate its removal. Should it be found that the gear does not readily come free its removal may be made more easy by taking off the gear on the lower sprocket shaft. However, this is usually not necessary and in replacing the lower sprocket shaft gear care must be used to see that the set screw seats properly on the "flat" provided for it on the shaft.

The removal of the movement itself may now be made. The movement is clamped to the center frame of the mechanism by two screws operating against sliding slotted washers. Loosen these screws a turn and slide the washers free from the flange of the movement casing. Grasp the balance wheel of the movement and draw the movement straight out until it is partly free from the center frame casting, then turn it about half a turn around when it will be found that it can be removed. Do this gently, working the movement around so

that the sprocket or other parts of the movement are not forced against the parts of the mechanism and so damaged.

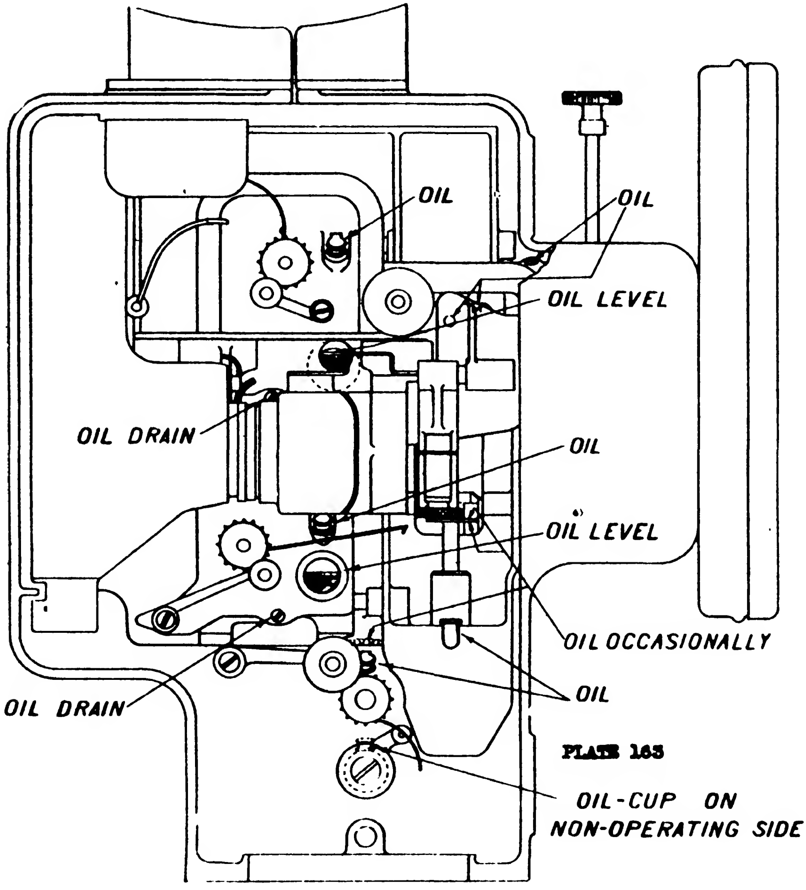


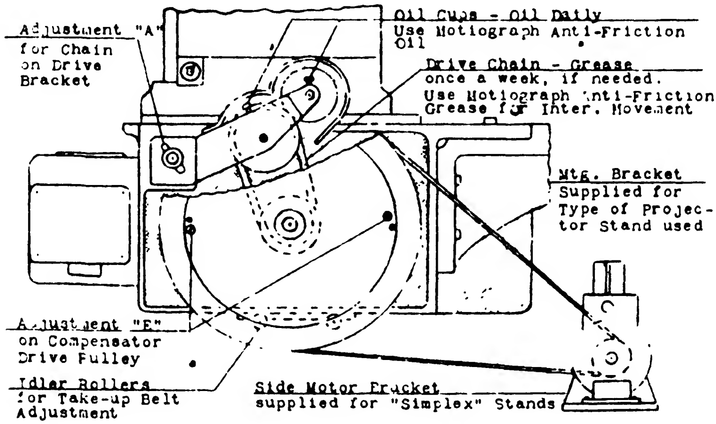
PLATE 163

Replacing the Movement

This is accomplished simply by a reversal of the instructions for its removal. In replacing see that the "notch" on the

flange rim of the movement casing engages with the locating stud at the top of the opening in the center frame casting into which the movement casing fits.

The casing of necessity fits tight into the center frame casting, therefore do not attempt to force or hammer it in place. If it is correctly positioned you will be able to seat it perfectly in place by working gently with your hands only.



Re-Setting the Shutter

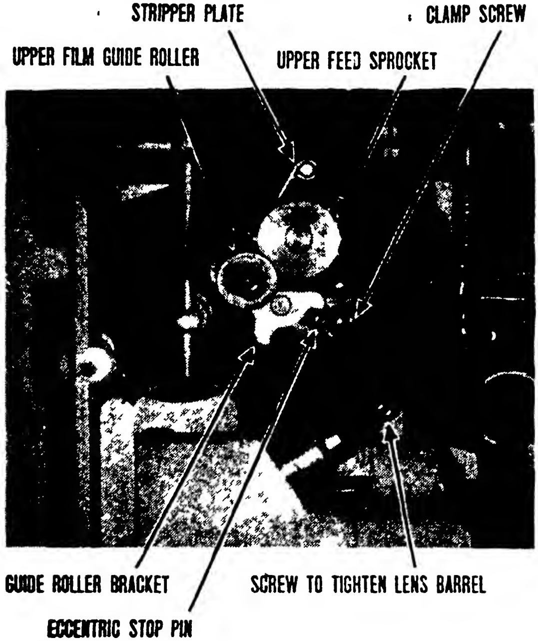
In replacing the movement, the original shutter setting will not be disturbed if the following instructions are observed.

With the movement in position and before adjusting the sliding washers and clamping screws, turn the balance wheel until the sprocket is just ready to move. The balance wheel must be turned in its correct direction. Then turn the balance wheel still further until two teeth of the intermittent sprocket have passed a given point. This will be equivalent to moving the film one-half a frame. At this point the active or cut-off blade of the shutter should be evenly spaced across the projecting lens. Or in other words, a line through the center of the shutter blade should be at the center of the lens. If the shut-

ter is not in this position, withdraw the movement sufficient to disengage the balance wheel gear from mesh with the gear on the shutter drive shaft and turn the shutter so that it will be in proper position when the gears are again meshed.

Removing Single Bearing Intermittent Movement

The same instructions given for removing the double bearing movement apply also to the single bearing movement supplied as regular equipment on the Motiograph Special Pro-

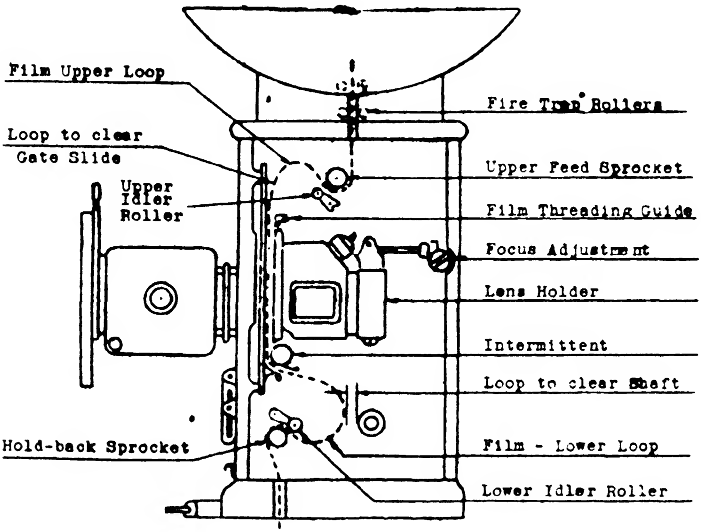


jector, except that in withdrawing the single bearing movement it is only necessary to turn it about a quarter turn instead of half a turn as in the double bearing movement.

Adjusting the Double Bearing Intermittent Movement

Before attempting to adjust either the double bearing or single bearing movement, the movement must be removed from

the mechanism. It is a mistaken idea that a movement can be correctly adjusted while in position in the mechanism. The correctness of the adjustment must be "felt" by turning the balance wheel by hand. With the movement in the mechanism, a whole train of gears is moved which makes it impossible to "feel" whether the adjustment of the movement is correct or not.

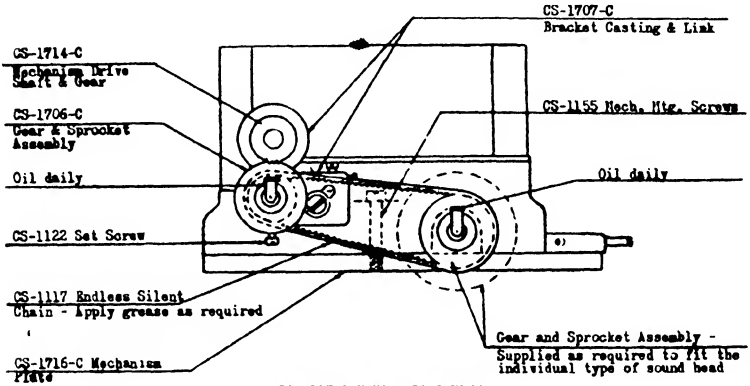


There are only three possible adjustments for the double bearing movement. These are the adjustment for end play of the intermittent sprocket or star shaft, adjustment for star and cam relation and adjustment for end play of the cam or balance wheel shaft. These adjustments should not be made until natural wear makes them necessary.

To adjust end play in the star or intermittent sprocket shaft, loosen the set screw in the outer bearing of the star shaft and press inward on the plunger projecting from the outer bearing and retighten the set screw.

To adjust the star and cam relation, first loosen the set screw near the inner bearing of the double bearing bracket. While both bearings of the star shaft are always in alignment

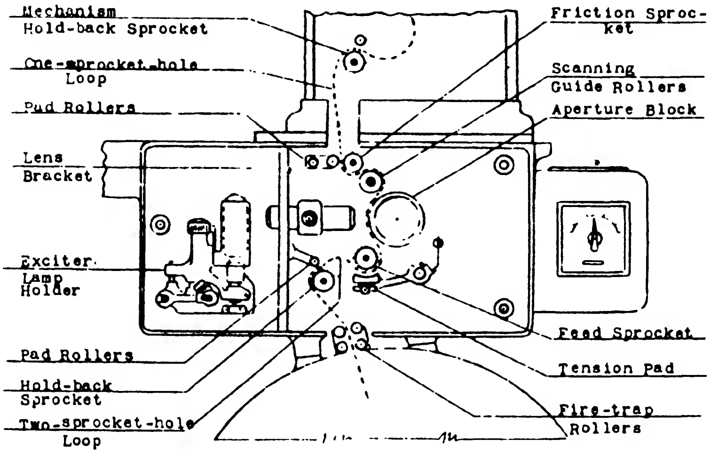
with each other, the outer circumference of the bearing next to the movement casing is made eccentric in relation to the center of the bearing hole for the star shaft, thus permitting the star to be adjusted to the cam without disturbing the alignment of the two star shaft bearings. This eccentric bearing is called the inner bearing. Now make the fine adjustment by means of the two screws on the adjustment bracket. These two screws operate against the projection on the double bearing bracket and provide micrometer adjustment. Back one screw off and tighten the other in the direction adjustment is desired. When adjustment has been completed retighten the set screw.



ASSEMBLY LAYOUT - SIDE VIEW

Under no circumstances should the star be adjusted so tightly against the cam rim that even the slightest bind or drag will be apparent when turning the balance wheel by hand. If too close an adjustment is made, undue friction will result. This will be evidenced by rapid wear and scoring of the star and cam surfaces where they come in contact and

they will be ruined. In addition the undue friction will develop heat and expansion of the parts which may result in a freezing or seizing of the working parts which will make the movement inoperative.



To adjust for end play of the cam or balance wheel shaft, loosen the two set screws on the side of the balance wheel. These two screws lock against two long screws which run through the diameter of the balance wheel and seat on two "flats" on the cam shaft. After loosening the first two screws, loosen also the two long screws. Now grasp the knurled retaining screw on the end of the cam shaft between the fingers and by pressing the balance wheel inward and drawing outward on the retaining screw, the balance wheel is pressed against the casing and the end play is taken up. Then reset the two long set screws and lock them by resetting the first two screws and the operation is completed.

Adjusting the Single Bearing Intermittent Movement

Recessed in the boss which forms the support for the eccentric bushing and located very close to the inner flange of the intermittent sprocket, will be noted the head of the eccentric

bushing locking screw. Loosen this screw about one-half a turn and fit the special eccentric bushing wrench over the hexagon boss of the bushing. The eccentric bushing can now be moved either upward or downward, which action will move the star either closer to or further away from the cam.

Observe the same precautions against too tight an adjustment as is noted under adjusting instructions for the double bearing movement.

Adjusting Idler Roller Brackets

The proper adjustment of the idler rollers makes it necessary that there shall be a distance equal to the thickness of two pieces of film between the rim of the idler roller and the face or flange of the sprocket. Looking inward to the mechanism, located very close to the pivot point of the idler roller bracket will be noticed a large flat headed screw. This is a clamping screw for the eccentric stop stud of the idler roller bracket casting. By loosening this screw and inserting a screw driver in the slotted end of the eccentric stop stud, same may be rotated to raise or lower the idler roller position in relation to the sprocket. When the proper adjustment has been obtained the large flat headed clamping screw is again tightened. As the idler rollers have been correctly adjusted when the mechanism left the factory there should be no occasion to make any adjustment until natural wear of the roller and sprocket face make it necessary. Careful attention should be given to see that the rollers revolve freely. Keep them clean and well oiled and free from accumulations of wax from the film. When a roller does not revolve it soon wears a flat surface. The roller is then useless and must be replaced.

Shutter Shaft Collar

The shutter shaft collar is composed of three separate pieces; the collar hub with set screw, the shutter flange with locating dowel pin and the hexagon tightening nut. The purpose of the separate flange is to make it adjustable so that when its dowel pin is entered in the dowel pin hole in the shutter hub, the shutter may be properly set in time with the intermit-

tent movement. An added convenience of this type of construction is that when once set, the shutter may be removed from the shaft and replaced without it being necessary to reset it, as when the dowel pin on the flange engages with the dowel hole on the shutter hub the shutter must again take its exact previous position. This also permits the interchange of two and three wing shutters without resetting.

In the event that the intermittent movement has been removed and instructions for resetting the shutter have not been followed, it may be found on replacing the intermittent movement that the shutter is out of time. To correct this it is only necessary to loosen the hexagon nut on the shutter shaft collar, move the flange to the proper position to locate the shutter correctly in time with the intermittent movement and tighten the hexagon nut again.

Shutter Setting Device

This device operates to provide accurate, fine adjustment of the shutter while the projector is in operation. It is placed on the take-up side of the mechanism and the adjusting knob will be found on the top front of the mechanism. Near the top of the front plate on the inside of the mechanism will be found a projecting boss through which the shutter setting device shaft passes. Directly under this boss will be found a hexagon nut through which the shaft also passes and under this nut a set collar. The purpose of the hexagon nut is to lock the shutter setting device so that it may not be unintentionally disturbed.

When mechanism leaves the factory the shutter is set as near accurately as factory conditions will permit and the shutter setting device is locked by setting up the hexagon nut. When the projectors are installed it may be necessary to refine the factory setting of the shutter by means of the shutter setting device.

First unlock the device by loosening the hexagon nut. Then while projecting film correct the shutter setting by turning the adjusting knob clockwise (or down) to correct "up travel" and counter clockwise (or up) to correct "down travel."

When the adjustment has been completed reset the hexagon nut to again lock the shutter setting device.

Film Gate

Removing the film gate is a very simple operation when one or two small intricacies are understood. To remove, pinch the two small hinge pins at the upper part of the gate together. At the same time lift up the door latch at the bottom of the gate and bring the entire gate assembly straight out toward the lamphouse. To remove it completely, it will be necessary to lift the small stop hook at the bottom of the gate and disengage the gate slide link. These generally fall out of place with the natural removal of the gate and it is seldom that any particular attention is paid to their disengagement.

In replacing the film gate, first see that the automatic fire shutter is in its closed position, now that the stop hook at the bottom of the gate is placed in position, then the gate slide link. Now place the top of the gate between the hinge pin bearings and after seeing that the small yoke of the automatic fire shutter is in position to engage with the working link on the mechanism, pinch the hinge pins together and slip the gate into position.

THE W.E. MIRROPHONIC REPRODUCER

This new reproducer consists of three units which interchangeably fit together to form a single symmetrical unit.

The main film compartment consists of a machine casing containing the film-propelling mechanism, gears, the kinetic scanner, and a sub-compartment in which the exciter lamp is located. The photo-cell compartment is attached to the rear end of the main casing, and is interchangeable. It contains the photo-cell, the scanning slit and the coupling transformer.

The motor assembly is attached to the forward end of the main casting as a unit, and is interchangeable, self-aligning, and can be replaced in a few minutes.

The film path is from the hold-back sprocket in the projector head, around the drum of the kinetic scanner, over the drive and hold-back sprockets, and thence to the lower film magazine.

The mechanical drive consists of a worm directly coupled to the motor, driving a gear at 360 rpm. This gear is on the cross-shaft that supports the main drive sprocket as well as the necessary gears for driving the projector head and the lower magazine take-up. The cross-shaft, as well as the worm shaft, is supported in sealed ball bearings, and their accuracy of alignment is held to a very close tolerance. The cross-shaft is coupled to the hold-back sprocket shaft by means of a set of steel and fiber gears; and in order to minimize noise, the lower magazine take-up is driven by a silent chain.

The lubrication is fully automatic. All shafts but the

one bearing the hold-back sprocket, and including the motor shaft, rotate in sealed ball bearings. The worm gear operates in oil in a sealed chamber in the main casting, and the hold-back sprocket shaft is rifle-drilled to permit lubrication from this chamber.

THE KINETIC SCANNER

The kinetic scanner is a completely sealed unit consisting of a hardened nitralloy scanning drum, ground to a concentricity of better than 0.0001 inch rotating on a shaft running in sealed ball bearings. It is a complete unit, mounted in the main frame casting. A two-element film speed governor, mounted upon the rear end of the shaft, insures uniform speed of film propulsion.

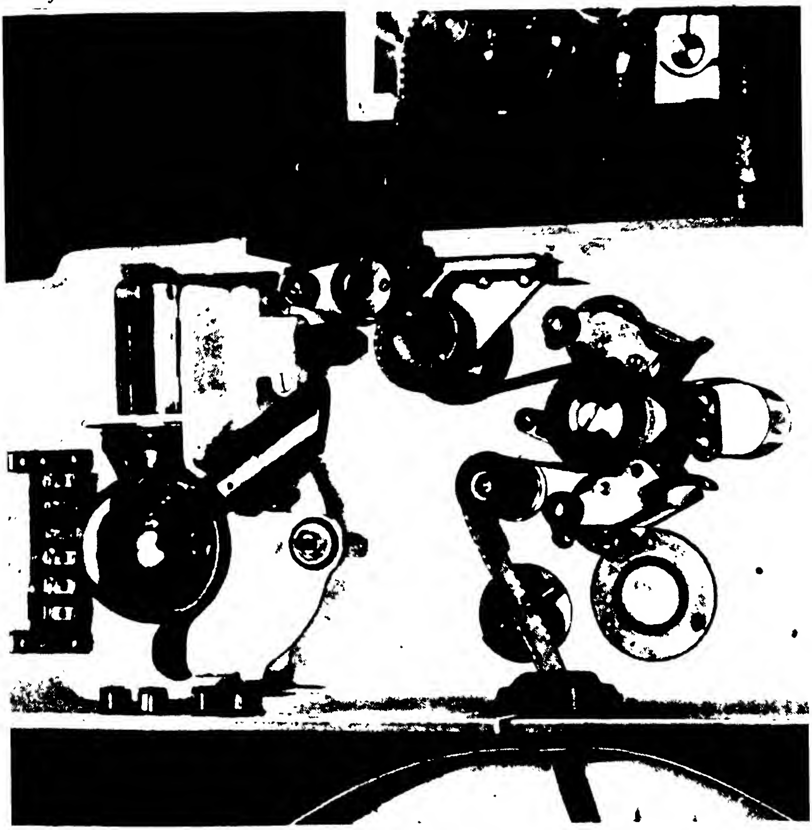
The film is held in contact with the scanning drum by a pressure pad roller which serves also to maintain scanning alignment. This assembly consists of a shaft, mounted on ball bearings, upon which is a felt pressure roller built up of a series of felt rings cemented together, thus assuring a uniform hardness of surface capable of maintaining its original concentricity. The felt roller is mounted upon a steel sleeve and is easily replaceable as a unit.

The optical system is the projection type of scanner. An exciter lamp is mounted in a pre-focussed lamp bracket having the usual adjustments, which is mounted upon a damped chassis merely by being pushed upon two locating studs and locked into place. The light is focussed upon the film by a condenser and prism combination mounted in a slot in the main frame casting which is adjustable along the optical axis for optimum setting.

The optical axis is fixed throughout by the exceedingly close manufacturing tolerances employed.

The objective lens is a standard microscope objective mounted upon a precision sleeve that provides movement along the optical axis for obtaining a sharp focus. This objective projects an image of the sound-track, magnified ten times, upon a scanning slit in the photo-cell compartment. Provision has been made for masking the width of the track scanned at the focal plane, thereby insuring

against the decrease of illumination at the edges of the beam that occurs when masking is attempted at points other than on the focal plane. The height of the slit is adjusted at the factory to be an optimum for the frequency range to be scanned. The azimuth of the scanning slit is readily adjustable.



The principal immediate advantage of projection scanning is its flexibility and simplicity of adjustment. It bids fair to take the scanning system out of the hands of the optical laboratory and place it with the projectionist, who will find the adjustments as simple as those he has always been accustomed to make in projecting pictures upon the screen. The magnified image of even an 8000-cycle sound-

track is so large that focus and azimuth can readily be adjusted by visual inspection, and will not be more than a decibel or so from the optimum obtained by the more laborious method employing the film loop and volume indicator.

A septum is provided at the center of the scanning slit for the reproduction of push-pull recordings. It is mechanically connected to the switch controlling the electrical circuits for reproducing either standard or push-pull sound-track.

ELECTRICAL CIRCUIT

The electrical circuit is in the photo-cell compartment, and consists of the photo-cell (which may be of the usual single-element type for standard track, or double element type for either push-pull or standard track) and a carefully balanced and shielded transformer having an impedance ratio of somewhat more than a third of a megohm to 200 ohms. The electrical balance between the elements of the cell and the coils of the transformer is such that no provision is required for equalizing the output from the two halves of a push-pull sound track, so that operation is simplified merely to throwing a switch for the type of sound track to be scanned.

From the installation and operating standpoints, the question of simplicity has been given serious consideration. With the selection of the correct pedestal arm, the reproducer set may be readily mounted upon any of the pedestals manufactured today in the U.S.A. Adapters are provided for the various projector heads in current use. The projector head is fastened to the adapter, which slides into a groove in the top of the main frame casting, providing a simple means of correctly meshing the reproducer and projector gears. It is possible, therefore, to remove the projector head, together with the adapter, by removing four readily accessible bolts, and to mount the projector head again without in any way changing the focus or alignment of the picture upon the screen. The flutter content of the average machine, measured in production, is about 0.1 per cent; and with special adjustment the machine is capable

of bettering this performance. The frequency characteristics conform to the theoretical response for a scanning beam of the height employed. The introduction of calculated damping materials insures that the machine introduces no noise during the quiet passages of the sound track.

THE W.E. 86-TYPE AMPLIFIER

The advent of the new Western Electric Mirrophonic sound-head called for an amplifier of new design, so the Bell Telephone Laboratories has recently developed the 86A, B, and C amplifiers. Incorporating the latest developments in vacuum tubes, transformers, and other elements, these amplifiers provide a gain of 98.5 db and an output level of approximately 15 watts. The circuits and mechanical arrangement of the three amplifiers are essentially the same; they differ chiefly in being arranged for different power supply frequencies and output impedances, in order that they may be adaptable to a wide range of uses.

As shown in the schematic these amplifiers have four stages: the three preliminary stages employing 262A vacuum tubes resistance-condenser coupled, and the power stage employing two 300A vacuum tubes in a push-pull arrangement. Transformer-coupling is used for the input to the first stage, and as input and output for the power stage.

The amplifiers are entirely a.c.-operated: the plates being supplied from a 274A vacuum tube, which rectifies the high voltage supplied by the power transformer, and the filaments being operated on low voltage obtained from the same transformer.

POWER TRANSFORMERS

The power transformers of all three amplifiers are designed to operate from a primary supply voltage between 105 and 125 volts. The A and B amplifiers are designed for 60 cycle circuits, and the C amplifier for either 50 or 60 cycles. All three may be operated continuously at room temperatures as high as 110 degrees Fahrenheit.

In a considerable number of sound-reproducing systems, auxiliary amplifiers or circuits are used for which small

amounts of plate and filament energy are required. To make it possible to supply this energy, the 86-type amplifiers are provided with excess power capacity and suitable connections from which one ampere at ten volts may be obtained for filament supply, and rectified and partly filtered plate currents of 5, 7.5, or 10.5 milliamperes at 400, 190, or 85 volts, respectively. This is sufficient to energize three W.E. 80A or 62A amplifiers. Two small filter units, the 714A and 716A apparatus units, have also been designed for providing the additional filtering required by the high-voltage energy used for auxiliary amplifiers.

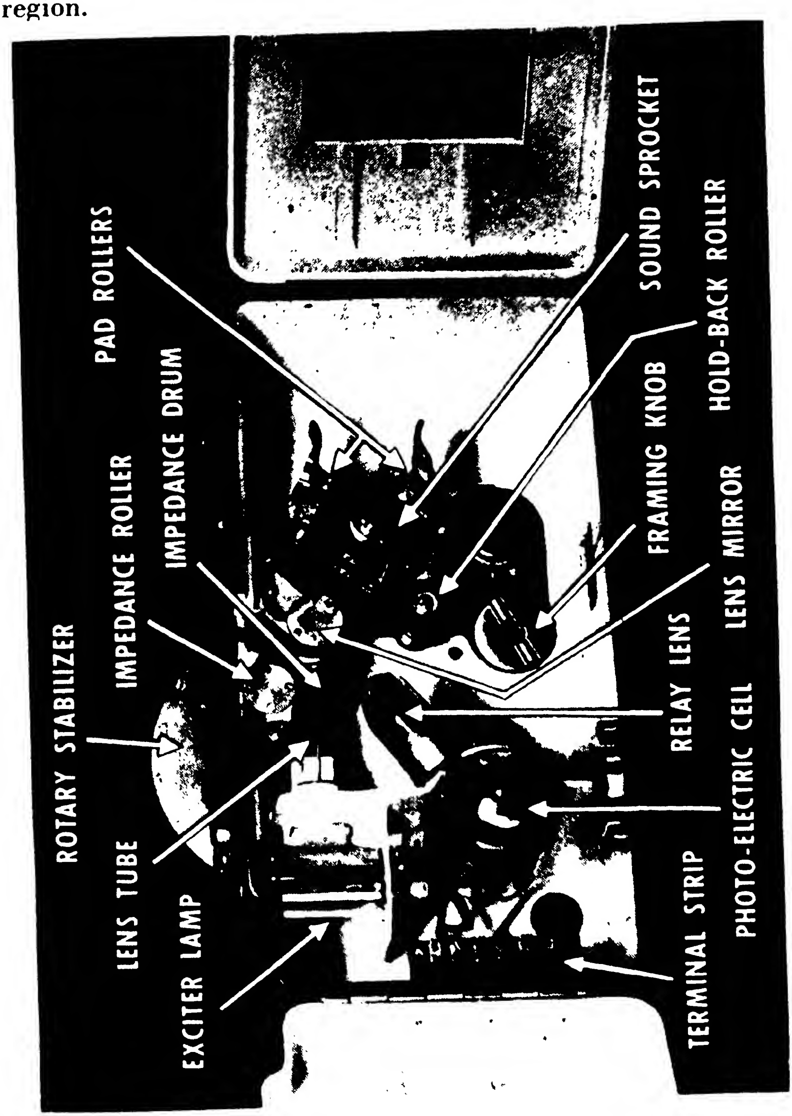
To aid in installation and servicing, means have been included in the amplifiers for measuring the space current of each vacuum tube and external "B" supply circuit. Current shunts have been soldered into each of these circuits and a rotary switch provided by which a special meter, known as the KS-7535, may be connected to any of the shunts.

All three amplifiers are designed to operate from a 200-ohm impedance, which is common practice for amplifiers of this type, but the output impedances differ. The 86A and 86C amplifiers operate into a load impedance of either 6 or 12 ohms, while the 86B operates into either 8 or 500 ohms. Continuous adjustment of gain is not provided, but fixed attenuators have been placed in the grid circuits of the three preliminary stages so that the gain may be adjusted over a wide range in steps of 5 db. These attenuators may be connected into the circuit by means of taps shown in the diagram.

Five-decibel attenuation is provided in the first stage; 10, 20, or 30 db in the second stage, and 10 db in the third stage. Connections from these taps are brought to a terminal strip beneath the chassis where connections for the desired gain may be made. In addition, one or two of the preliminary stages may be cut out of the circuit. By these means the gain of the amplifiers may be adjusted in 5 db steps from 38.5 to 98.5 db.

The gain-frequency characteristic is the same for all three types, and is essentially flat from 50 to 12,000 cycles. The

power output characteristics of the 86A and B amplifiers are similar, showing an output level of 15 watts over the major portion of the frequency band; while the 86C amplifier characteristic is more uniform in the low-frequency region.



The sound system is placed in operation by installing exciter lamps, photocells, and vacuum tubes in reproducers, power unit and amplifiers in accordance with their respective equipment bulletins and diagrams, and then applying A. C. power to the power unit and amplifiers. The amplifier switching panel switch should be turned to its "1" position, and the monitor volume control knob on the No. 1 (upper) amplifier advanced to nearly full-on position.

Reproducer optical system adjustments should be checked, and a test for output from both reproducers should be made by advancing the PA-7505-A Amplifier main volume control to midscale (step 10) position, and the changeover switch handle to R (right) or L (left) position respectively while the light path in the appropriate reproducer is momentarily interrupted at a fairly fast rate with a card or other object. This operation should produce audible thumps from both the monitor speaker and the stage loudspeaker system. When sound is obtained from both reproducers, the final changeover switch adjustments should be made.

When the system has been checked as outlined using No. 1 amplifier, the switching panel switch should be transferred to its "2" position, and the monitor volume control of No. 2 amplifier advanced. The same checks for sound as before should be applied, though they need be carried out on only one reproducer.

When it has been determined that both amplifiers are functioning, their operation in parallel may be tested by setting the switching panel switch to it's center, or "1 & 2" position, and repeating the checks. In this position the auxiliary monitor amplifier stage of the No. 2 amplifier only is connected to the monitor speaker, and power for the PA-7505-A Amplifier circuits is supplied from the No. 1 amplifier.

CHECKING WITH CIRCUIT TESTER

If difficulties show up, check all connections through with a circuit tester such as a buzzer and

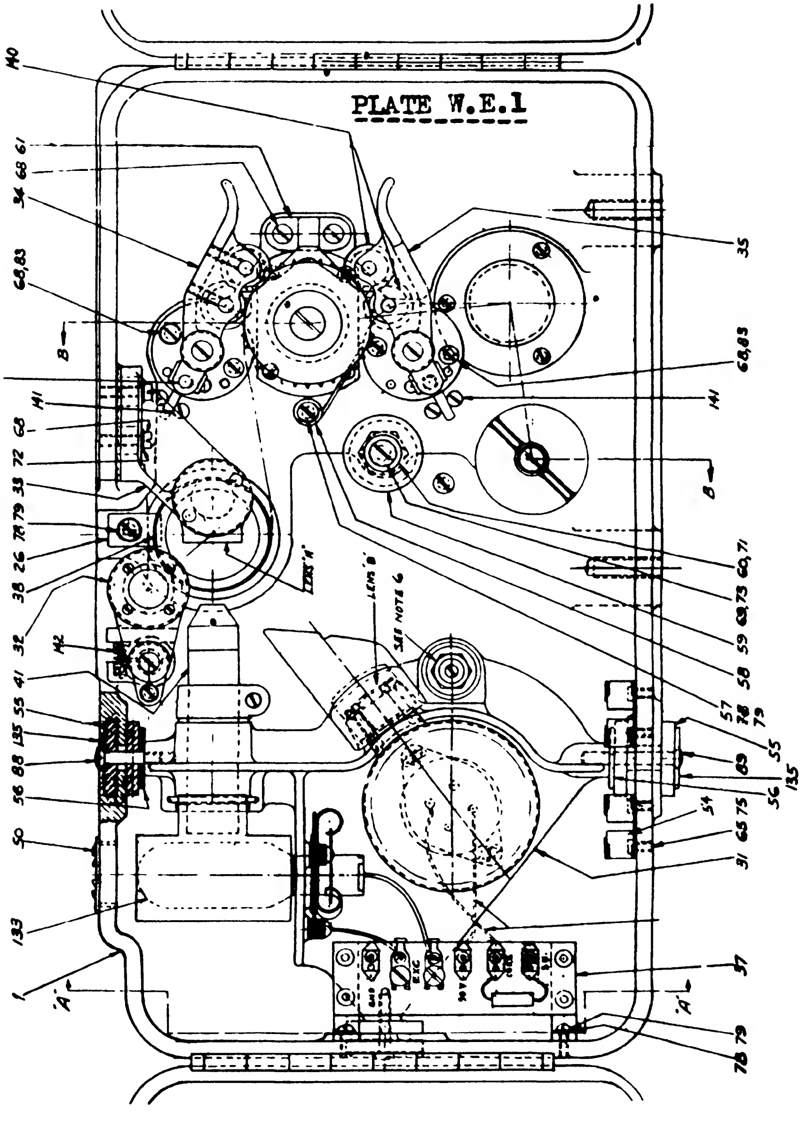


PLATE W.E.1
LENS 'A'
LENS 'B'
SEE NOTE 6
B
'A'

battery, or an ohm meter. Voltage checks at amplifier and reproducer terminals are also useful, and the possibility of defective or damaged vacuum tubes should not be overlooked. While system components are carefully checked and given operational tests before shipment, it is of course not impossible for them to get out of order during transit or in handling during installation. By far the most common source of difficulties at installation time, however, are misconnections, or omission of connections. Noise and hum pickup, even though sound circuits and power circuits are complete, may be due to such causes as omission of ground connections, or to reversal of core and shield connections involving Belden No. 8401 coaxial cable.

CHECKING SOUND QUALITY

After it has been determined that all sound circuits are complete and that the system is free from noise, sound films may then be threaded into the projectors and reproducers and sound quality checked in the auditorium. Frequency response runs, using standard multi-frequency sound test films, are always desirable to check the operation of reproducers and amplifiers, and the information they provide is almost indispensable to proper equalization and loudspeaker system adjustments for optimum auditorium sound quality.

THE SWITCHING PANELS

The SE-7512 Switching Panel has an auxiliary terminal strip on the front, or operating surface of the panel to facilitate system frequency response and other measurements. This strip has a grounded terminal and two others connected by a removable link inserted in the ungrounded side of the switching panel's sound output circuit to the stage loudspeakers. By opening the link and connecting a suitable resistance between the "AMP. OUT" and "GND" terminal, with the usual volume indicator meter also connected to these terminals, the necessary load conditions for such measurements are quickly and conveniently set up. The link

must of course be in place during normal operation. Headphones of 500 ohms, or higher impedance may be connected from the link to the ground terminal for close sound monitoring with little effect on the circuit to the stage loudspeakers.

The output of the SE-7501 Monitor is controlled by the knob on the meter panel of whichever MA-7505-A Amplifier is in use singly, and by the control on the lower (No. 2) amplifier when they are operated in parallel.

The switching panel switch should not be operated during a performance except in case of emergency as heavy clicks in the system output result from breaking and making the various sound and power circuits. Where it is customary to operate the amplifiers singly due to low power requirements, it is desirable to change off from one to the other at about weekly intervals in order to insure that the standby amplifier is always in good order.

AMPLIFIERS—FREQUENCY RESPONSE

For the two amplifiers to operate properly in parallel and deliver twice the maximum rated output of either alone, it is essential that they both be equalized with respect to frequency response in the same manner, and that they have approximately the same gain (amount of amplification) at the reference frequency (usually 1000 cycles). Complete frequency response runs on each amplifier are the most accurate means for checking balance; next are output measurements, at the reference frequency provided by an oscillator or 1KC frequency film loop, or at 120 cycles obtained by letting light from a lamp operating on 60 cycle current fall upon one photocell; last, but usually satisfactory, are listening tests on some recording having reasonably steady modulation level.

The main volume control dial of the PA-7505-A Amplifier controls both reproducer outputs in steps of approximately 2 db. It is therefore necessary that right and left output signal levels at the changeover switch be the same. The best possible balance should

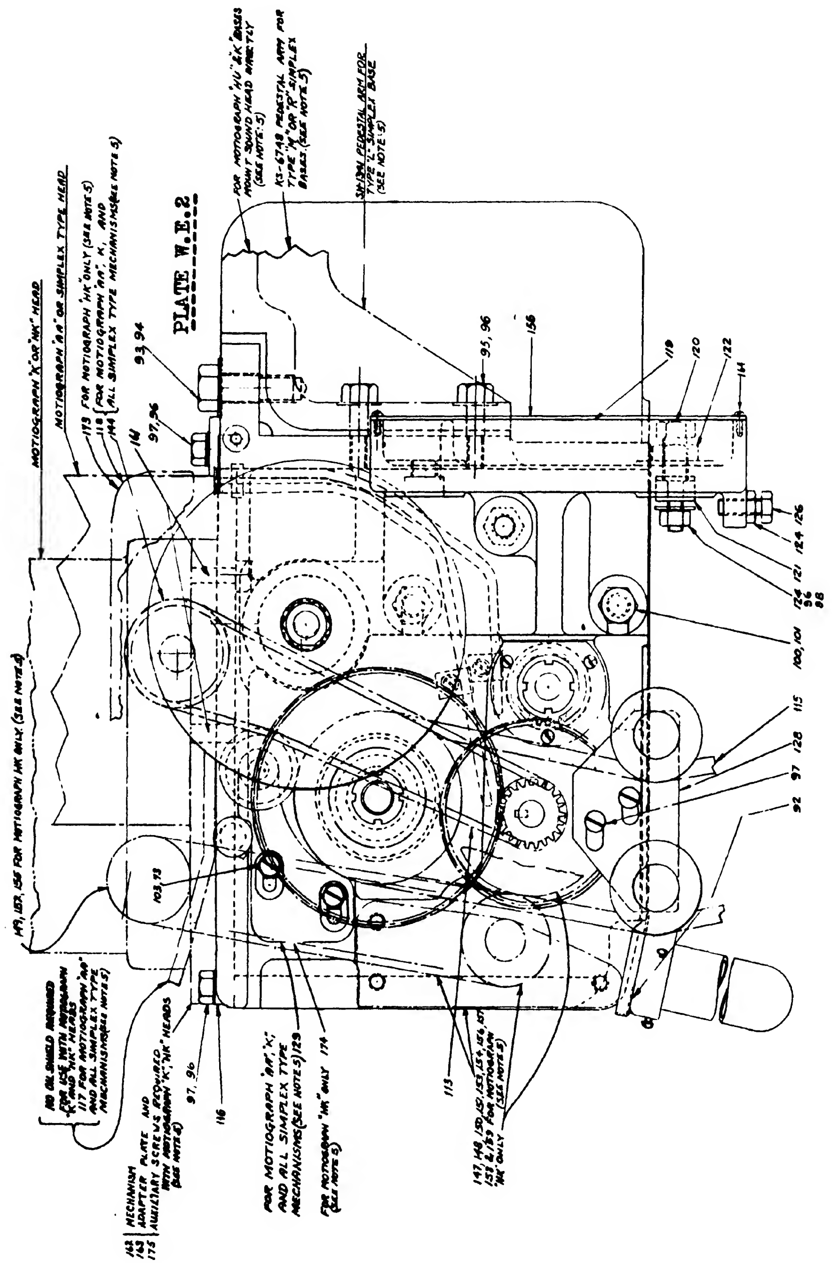


PLATE W.E.2

first be obtained by interchange of exciter lamps, photocells, and input tubes in the preamplifier input stages, (including spares) since efficiencies of these components vary considerably. Then lower the signal level of the higher input as required with the auxiliary balancing control knob on the appropriate side of the PA-7505-A Amplifier chassis between the input tube and the center tube. Academy 1KC balancing film loops are recommended for accurate balancing. If these are not available, two reels from a feature picture may be used if care is taken to select sections of dialogue of average volume level.

It is usually desirable to have the overall system gain (amplification) be such that average feature pictures run at about step 9 or 10 on the main volume control so that sufficient range of adjustment will be conveniently available to take care of very low level prints and also those, such as newsreels, with very high modulation levels. The system gain may be varied over a range of 6 db. (3 volume control steps) by changing the position of the grid lead to the input tube of the MA-7507-A Amplifier on its multi-unit grid resistance as outlined in the amplifier bulletin. The auxiliary balancing controls mentioned in the preceding paragraph may also be used for this purpose, though since they are provided primarily for balancing purposes, any such use necessarily restricts the amount of balancing range available. Abnormally high volume control settings for prints known to be of average level are usually indications for trouble somewhere in the sound system.

MAINTENANCE AND TROUBLES

Periodic, regular servicing of the sound system is highly recommended. No electro-mechanical equipment is completely immune to gradual deterioration of performance with time, and to failure of component parts. Competent, regular servicing is the best possible insurance, second to having high grade equipment, against loss of show time. Servicing should include, as a minimum, inspection of connections and compon-

ents, testing of vacuum tubes, checking of all adjustments, and such periodic operational tests as frequency response and gain measurements, power output measurements, system noise level checks, and auditorium listening tests using test films of known good quality.

DISTORTION

Excessive distortion in the reproduced sound may be due to weak or defective vacuum tubes, damaged loudspeaker units, failure of some amplifier component, bad connections, improperly adjusted reproducer components, and many other causes including poor sound recordings.

LOW SIGNAL-TO-NOISE RATIO

Low signal-to-noise ratio may be due to defective exciter lamps or photocells, any of the causes listed in following paragraph resulting in higher than normal gain control settings, worn and badly scratched film sound tracks, failure of some amplifier or power unit component, etc. A quick check of noise possibly originating in the amplifier system is afforded by placing the changeover switch in its OFF position, which leaves all amplifier tubes in operating except the PA-7505-A Amplifier input tubes. Noise originating in the electrical circuits of the power unit, reproducers, or amplifier input stages may be checked by listening successively to the reproducer outputs at full amplifier and monitor gain with the machines at rest. This test is also useful in showing up such things as bad connections, tubes with internal defects, noisy resistors or condensers, etc., for noise will be evident when the faulty part is tapped or pushed with an insulating prod such as a wooden stick or bakelite rod. If the system is quiet at full gain with the machines at rest, check for excessive machine noise by reducing the amplifier gain to the normal operating point and operating the reproducers without film; the machine noise should be inaudible, or barely audible at the stage loudspeakers, and if it is more so, the cause should be investigated and corrected. If all these tests show

the system to be quiet, and if observation indicates that the reproducer impedance roller ("film guide roller") is properly adjusted to align the film sound track with the light beam from the lens tube, it is then reasonably safe to conclude that the poor signal-to-noise ratio is due to the film itself.

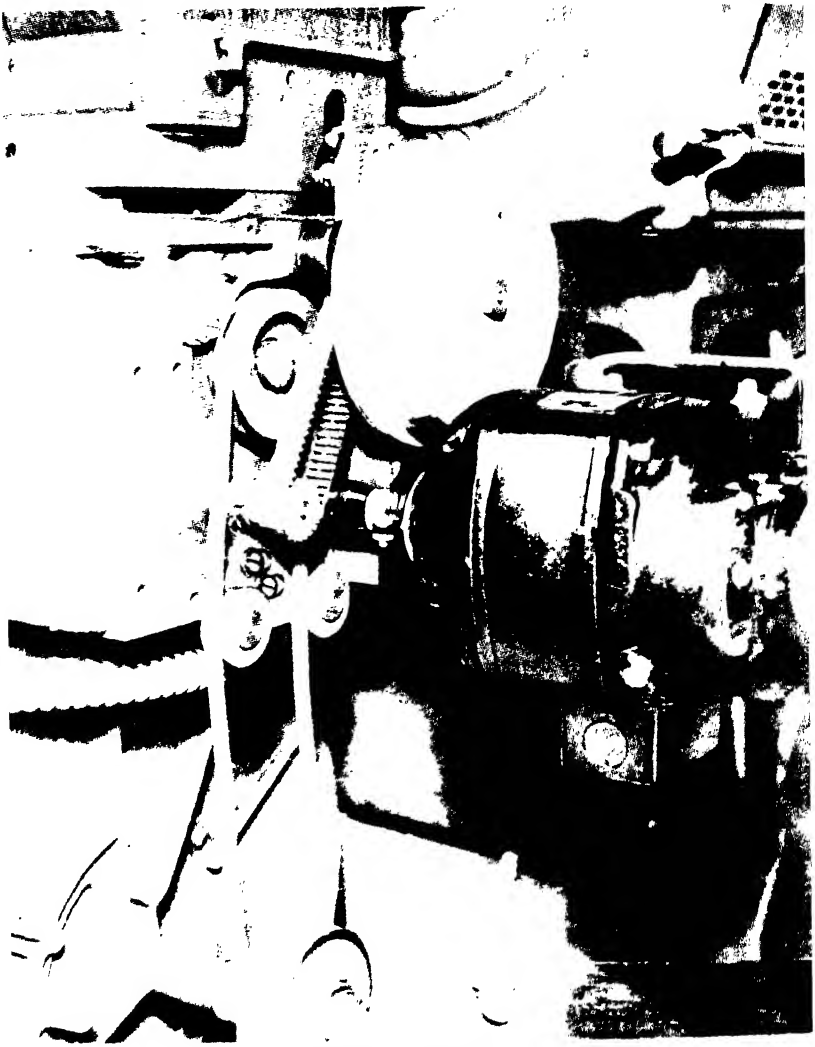
HIGH VOLUME CONTROL SETTINGS

Abnormally high amplifier volume control settings, usually accompanied by low signal-to-noise ratio, for prints known to be of average level are frequently indications of improperly adjusted exciter lamp current, deteriorated or defective exciter lamps, light losses in the reproducer optical system resulting from dirt or oil on glass surfaces, poor adjustments, damaged mirrors and lenses, etc., and of photocells of low or deteriorated sensitivity. Low amplifier gain, particularly in the input stages, due to weak tubes or component failure might also cause these symptoms, but such cases are less common.

The two exciter lamps are operated in series from the output of the power unit. If one burns out, both go out. The burned-out lamp can be located very quickly by momentarily shorting the reproducer EXC. terminals, first on one and then on the other reproducer. The good lamp will flash when the burned-out lamp is short-circuited in this manner; the short should be left in place only for an instant, since it causes excessive voltage at the good lamp. Another procedure about equally fast is to replace both lamps if one burns out; the open lamp can then be found by testing later. With either procedure it is advisable to shut off the PLATE switch on the power unit while the new lamp or lamps are being installed in order to prevent destructive arcing at the lamp socket contacts.

W. E. MIRROPHONIC REPRODUCER

The film movement stabilizing system is of the "rotary stabilizer" or "kinetic scanner" type. There are three major components, the impedance drum assembly, impedance roller assembly, and the rotary stabil-



SH-7500 REPRODUCER

izer proper. The drum assembly, consists of a heavy shaft supported in the drum by ball bearings; the inner end extends into the reproducer film compartment and carries a smooth-faced roller to support the film in the correct optical plane for sound track scanning. The outer end on the drive side of the reproducer carries the rotary stabilizing assembly. The impedance roller assembly consists of a small swinging bracket carrying a felt-faced, flanged guide roller to hold the film on the impedance drum roller and to guide it laterally. The rotary stabilizer is a hollow shell enclosing a heavy inner ball-bearing mounted flywheel. The shell is rigidly fastened to the impedance drum shaft and hence rotates with it. Force to rotate the inner flywheel is transmitted to it via a viscous liquid filling the space between the flywheel and the shell.

Film from the projector mechanism lower feed sprocket passes counter-clockwise around the impedance drum roller and on to the reproducer's sprocket.

In operation, there is a small amount of slack film on each side of the scanning point. These slack film loops, in combination with the inertia of the whole rotating assembly, effectively prevent such motional disturbances as those produced by sprocket teeth entering and leaving film perforations from reaching the scanning point. Very steady film motion at the scanning point is assured by the simple flywheel effect of the complete rotating assembly plus the stabilizing action provided by the viscous-damped compound flywheel, or "rotary stabilizer."

The reproducer sprocket is twice the diameter of conventional sprockets and rotates at half the usual speed. This aids in the stabilizing action, reduces both film and sprocket wear, and permits the sprocket to be used both as a sound sprocket to pull film through the reproducer and as a holdback sprocket. Double pad rollers, top and bottom, securely hold the film in place on the sprocket.

OPTICAL SYSTEM

The optical system consists of a 9 volt, 4 ampere

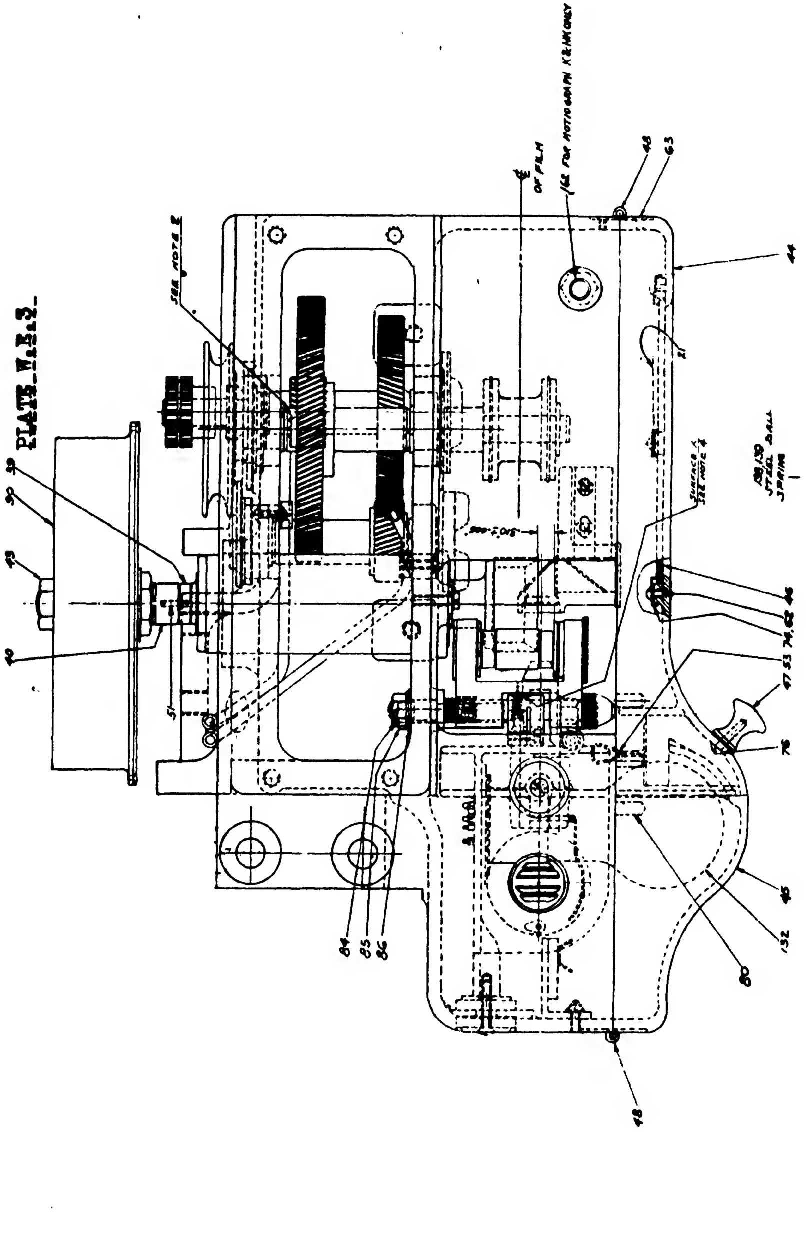


PLATE W.E.3.

prefocus base exciter lamp, a slit and lens tube assembly for producing the very thin, intense beam of light required at the scanning point, and a lens-mirror bracket assembly to collect the light after it passes through the film sound track and direct it to the photocell mounted below the exciter lamp. A small relay lens just above the photocell permits the location of light spot on the cell cathode plate surface to be adjusted so the beam clears the cell anode wire.

With the drive unit installed in the projector mechanism the assembly may be placed on the reproducer. For mechanisms mounting directly on the adapter plate, the drive chain may be put in place on its sprockets by sliding the plate forward in its slot sufficiently. Motiograph K mechanisms are pushed forward on their adapter plates while the drive chain is put in place. After returning the mechanism to its normal position, install the chain idler Item 129, Plate W.E.-2, and adjust it so the chain runs smoothly without whipping, and so that the bakelite idler roller touches the chain with just sufficient force to insure rotation of the roller. Sprocket alignment should be checked with a straight edge; reposition Item 111, Plate W.E.-4, Drive Sprocket on its shaft if necessary.

To assemble the drive components first replace the existing gear or sprocket on the existing mechanism drive shaft with the Item 152, Plate W.E.-2 Sprocket supplied. Place Item 153, Plate W.E.-2 Chain over the sprocket and hang Item 147, Plate W.E.-2 Sprocket and Gear in the chain loop. Install Item 174, Plate W.E.-2 Idler Assembly in minimum tension position and then fasten the mechanism to its Adapter Plate, Item 163, Plate W.E.-2, with the regular mounting screws. Insert Item 151, Plate W.E.-2, through Item 147, Plate W.E.-2, into Item 150, Plate W.E.-2, Bracket and lock it in place; a shoulder on the shaft provides for correct end play. If Item 150, Plate W.E.-2, Bracket has not been disturbed since final reproducer testing the gear mesh will be correct. If the bracket has been moved or if the drive components are being assembled for the first time, adjust the bracket position for

minimum gear backlash consistent with quiet operation and so that chain tension is under control of its idler assembly. The tension should be sufficient to insure rotation of the bakelite idler roller and smooth chain travel without binding or whipping.

DRUM ASSEMBLY

Check the Impedance Drum Assembly, Item 38, Plate W.E.-1, for free rotation of its shaft and film drum member. There should be no sign of binding or sticking and no more than the just perceptible end play characteristic in single row ball bearings. If the shaft binds or sticks, try tapping the shaft lightly at the film drum end with the wooden handle of a screw driver; the rear bearing is a slip fit in the housing to allow for shaft expansion or contraction due to temperature changes, and the tapping will usually seat the bearing correctly for minimum bearing loading.

Remove the tape which holds the shaft spacers in place over their Woodruff key during shipment. Try the Item 90, Plate W.E.-3, Rotary Stabilizer on the shaft to see that there is no binding due to dirt or burrs in its shaft hole. Then, holding the drum assembly in one hand, partially insert it into its hole in the reproducer center wall, lifting the impedance roller meanwhile with the other hand to clear the drum. When the shaft end appears on the drive side of the reproducer, place the stabilizer in line with it and gently work the drum assembly to its seat, at the same time inserting its shaft through the stabilizer. Lock the drum in place with its retaining clip, and lightly tighten the stabilizer retaining nut on the shaft end, taking care that the tongues on the shaft collar enter the corresponding notches in the stabilizer hub. Restore Item 33, Plate W.E.-1, Lens-Mirror Assembly to its seat at the top of the reproducer film compartment after checking it for lens and mirror cleanliness.

The impedance drum shaft and associated stabilizer, the film drum, and the impedance roller, which bears on and is driven by the film drum, should all rotate very freely and should have a long coast-down

time after being brought to approximately film speed by hand. It should be possible to feel the inertia of the heavy inner flywheel of the stabilizer resisting suddenly applied hand turning force to the outer shell, and once in motion, the rotational energy of the inner flywheel should restart the shell via the coupling and damping fluid if the shell is momentarily stopped by hand. This restarting or "pickup" effect is not as prominent, however, as in some earlier designed and much lighter rotary stabilizers, since the magnitude of the coupling and damping action must be properly proportioned to the weight of the rotating members in the film motion stabilizing system.

REAR GUARD ASSEMBLY

Attach the rear guard assembly, Item 118, Plate W.E.-2, and see that there is no interference with any rotating reproducer component. In the case of Item 173, Plate W.E.-2, the auxiliary chain guard must be positioned over the chain with the oil cup for the Item 151, Plate W.E.-2, shaft passing through the clearance hole in the guard. The auxiliary guard may need to be adjusted slightly on the main guard casting to provide adequate clearances.

Install conduit and wiring to the reproducer in accordance with sound system diagrams. Motor starting current under normal load conditions is 15-18 amperes, so switches in the motor circuit should be of at lease 20 ampere rating.

The SH-7500 Reproducer is normally supplied as a component of Motiograph-Mirrophonic Sound Systems; the photocell circuit includes a 2 megohm coupling resistor mounted on the terminal strip. Other amplifier systems having this coupling resistor in the amplifier input circuit may be connected to the reproducer by connecting the input coaxial cable to the reproducer "90 V" and "CORE" terminals, which are respectively the photocell anode and cathode loads. Note, however, that the cable core must go to the "90 V" terminal, and the cable shield to the "CORE" ter-

minal in this arrangement for correct cell polarization.

All Motiograph-Mirrophonic Systems include a power unit for supplying reproducer exciter lamps with direct current. The 9 volt, 4 ampere lamps of SH-7500 Reproducers associated with systems having no such power unit may be operated on alternating current from stepdown transformers of suitable rating, though reproduced sound quality will be inferior due to the resulting hum. If AC excitation must be used, somewhat better signal-to-hum level, at roughly the

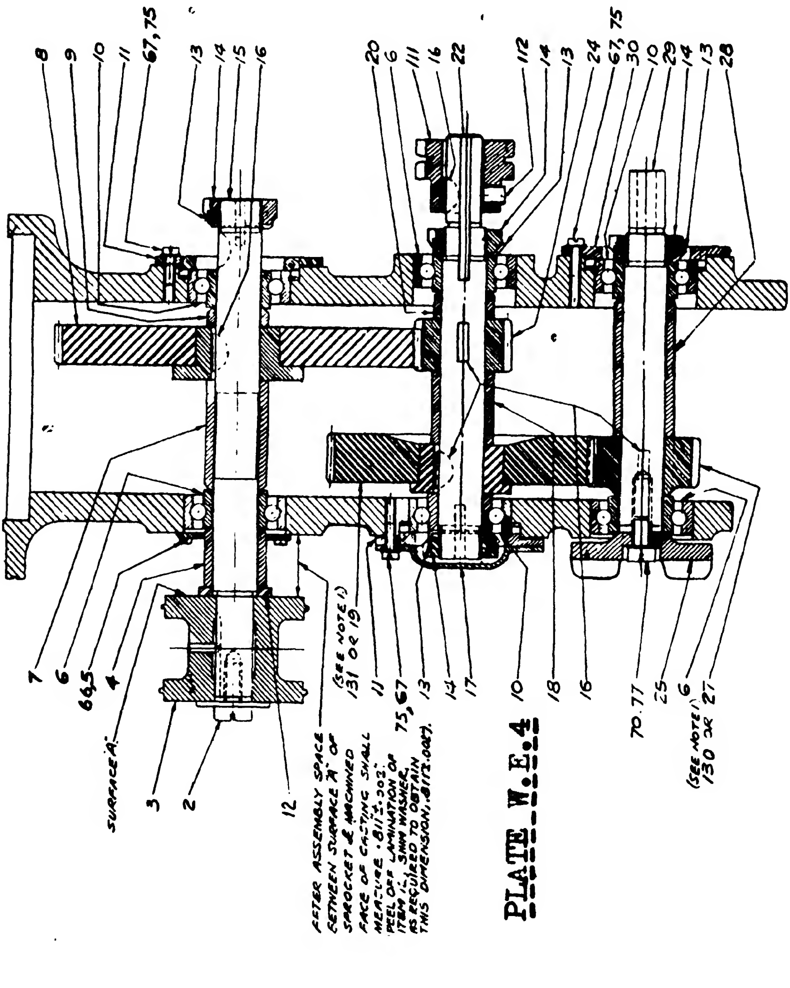


PLATE W.E.4

same output level, may be obtained by substituting 10 volt, 7½ ampere lamps operated at approximately 5 3/4 amperes. The improvement is due to the heat storing action of the heavier filament in the 10 volt, 7½ ampere lamp.

Install the reproducer exciter lamp and photocell in their sockets. Rotate the lamp until the locking eyelets in its prefocus ring drop over the socket locating

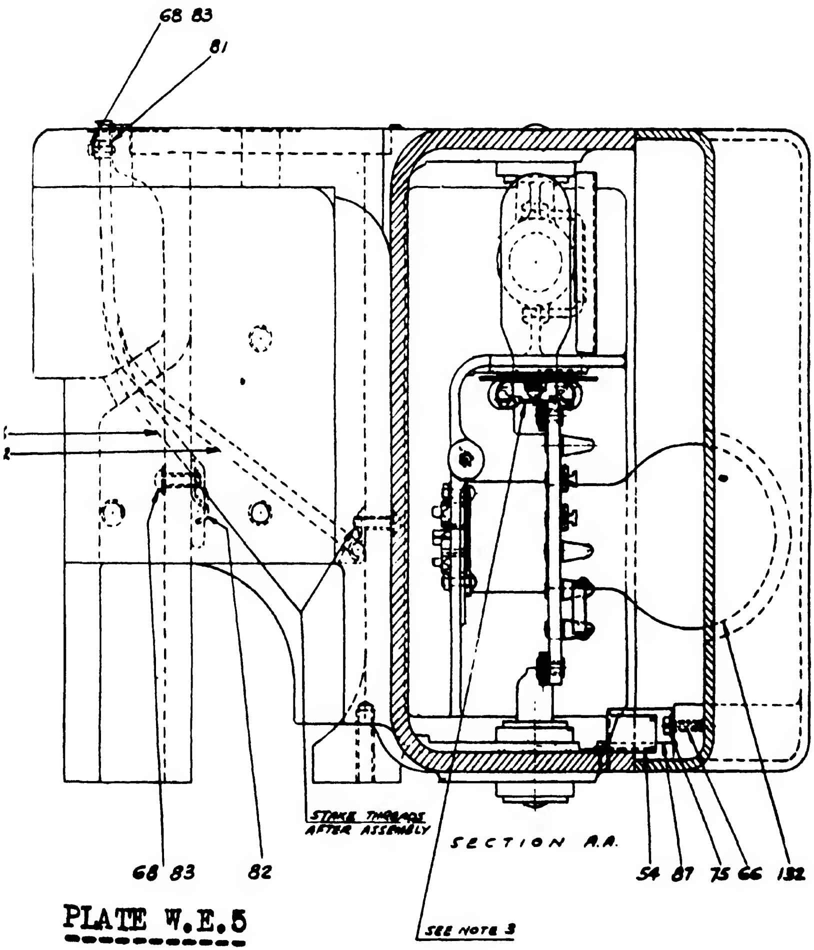


PLATE W.E.5

pins; press downward on the lamp and turn it clockwise to lock it in the socket. Lamps are most easily removed, particularly when they are hot, by first prying the ventilation cap out of its hole in the reproducer housing over the lamp. Press downward on the lamp through this hole with a cloth protected finger, and turn counter-clockwise the relatively cool lower part of the lamp bulb with the opposite hand to unlock the lamp from the socket. Removing the ventilating cap also gives additional clearance for the lamp bulb during installation or removal.

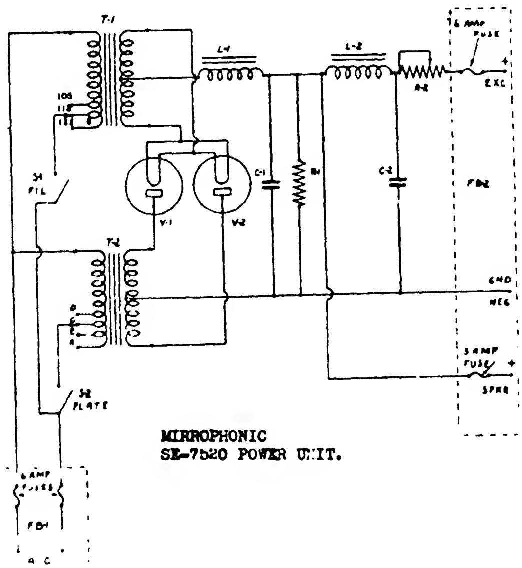
After installing the photocell in its socket, replace the cover, taking care that the locating slot in the cover edge is over the locating pin in the cover base so as to properly align the light aperture.

ADJUSTMENTS AND OPERATION OF SOUNDHEAD

Turn on the exciter lamp power supply and check the path of the light beam from the lens tube, Item 41, Plate W.E.-1, through the lens mirror assembly, Item 33, Plate W.E.-1, and the play lens assembly on the photocell bracket to the cathode (the cylindrical plate) of the photocell. A small white card held inside the film drum should show the light field coming through the lens tube with the bright filament image approximately centered up and down in the field. The lens in the Item 33, Plate W.E.-2, lens-mirror assembly shrinks the field to a narrow beam again, and in combination with the two mirrors, focuses this beam as an image of the lens tube slit on the relay lens just above the photocell. The front mirror is mounted in a plug which can be rotated as required to center the image on the relay lens, and the image is brought to focus by moving the entire lens-mirror assembly forward or backward as required in its mounting groove in the inside top surface of the reproducer frame casting.

The relay, or "collector" lens provides a means for locating the light beam to the photocell cathode so that it does not strike the cell anode wire enroute. The beam is small and interference with the anode

wire would cause loss of output signal level, and possible distortion from variable area type recordings. Photocell anode wires vary considerably in position, so the adjustment must be made whenever a cell is installed or replaced. It is made by loosening the two screws which fasten the relay lens bracket to the main bracket; the bracket has large clearance holes so it may be positioned as required. After positioning the light spot on the cell cathode, recheck the centering of the slit image on the relay lens, using a small card or paper held immediately in front of it, and adjust the plug-mounted mirror in Item 33, Plate W.E.-1, if necessary. With the photocell cover in place, slide the paper or card over its light aperture opening and see that the light beam properly clears the edges of the opening. There must be no interference anywhere along the light beam path and the light spot on the photocell cathode should be clear and distinct.



MIRROPHONIC
SE-7520 POWER UNIT.

Turn on the sound system amplifiers and speakers and check for sound output from the reproducer by interrupting the light beam with a finger or card.

Heavy thumps should be audible from the speakers and with the amplifier gain or volume control at maximum setting it should be possible to hear the characteristic "rush" or hiss of the photocell action under the influence of the light beam. With the gain up, tap the exciter lamp and the photocell to make certain they have no internal bad connections.

Lubricate the reproducer and thread sound film into the machine. The film path through the reproducer is exceedingly simple; from the projector mechanism lower feed sprocket the film passes counterclockwise around the film drum (emulsion side toward light beam) and thence over the top of the large sound sprocket. Pull the film up tight and then back it off to allow a minimum of one sprocket hole slack and maximum of two holes slack. Close the upper sprocket pad roller assembly and see that film is properly seated on the sprocket teeth and between the flanges of the impedance roller. Allowing a three-finger loop at the right of the sound sprocket, thread the film back along the bottom of the sprocket and over the film idle roller, Item 59, Plate W.E.-1, into the lower magazine. Close the lower sprocket pad roller assembly and check for film seating on the sprocket and for absence of any slack film in the lower magazine.

Start the machine and observe the action of the film as it passes over the idler roller, Item 59, Plate W.E.-1. If an initial loop of any appreciable size forms at this point, increase the takeup clutch tension until the tendency just disappears. The tension must be sufficient to overcome the inertia of the reel almost instantly and this requirement, particularly in certain clutch designs, is inconsistent with tension adjustments based on gauge or feel tests. The takeup drive belt must obviously be free from slippage and there must be no binding of the real shaft and no interference between reel and magazine if the tension adjustment is to be properly made.

Observe film passage through the reproducer.

Slack film loops on either side of the scanning point should be reasonably steady and the sprocket pad rollers should revolve freely during passage of film splices; outer pad rollers will usually revolve continuously since film contacts them over a considerable area. Any sticking of rollers, excessive mechanical noise, or undue disturbance of film loops should be investigated and corrected if possible. Disturbances of the upper film loop may be due to poor alignment between projector and reproducer, badly hooked teeth on projector lower feed sprocket, or dirt on, or damaged impedance roller surfaces.

Laterial adjustment of the impedance roller assembly ("guide roller") for correct alignment of sound track and light beam may be checked with standard buzz-track film if desired but it is much easier and sufficiently accurate to observe the alignment visually by placing the head at the front of the reproducer and looking at the track itself as the beam passes through it. If adjustment is necessary, loosen the lock screw in the center of the knurled adjusting nut on the roller bracket and turn the nut clockwise to move the film inward to eliminate noise pickup due to the beam striking sprocket holes or counter clockwise to take out noise resulting from light striking picture frame lines.

The double pad roller brackets for the sound sprocket are adjusted for lateral alignment of their roller flanges with the sprocket in the same manner as the impedance roller bracket. Clearance should be equal on each side. Roller film contacting shoulders should clear the sprocket by two film thicknesses. If adjustment is required, loosen the locking screws, Item 141, Plate W.E.-1, for the stud base several turns and loosen the mounting screws, Item 68, Plate W.E.-1, enough to permit movement of the stud. Place two thicknesses of film on the sprocket and press the entire bracket assembly and rollers down against it while the mounting screws are retightened. Then tighten the cone-shouldered locking screws little by little against the lock stud to rigidly anchor the assembly in place,

taking care that they do not disturb the adjustment.

The reproducer motor bracket incorporates several adjustments for exactly aligning the motor shaft with the reproducer drive shaft. The later adjusting screws, Item 120, Plate W.E.-2, are reached by removing the bracket cover plate, Item 156, Plate W.E.-2. The vertical adjusting screws, Item 126, Plate W.E.-2, are tapped into lugs at the bottom edge of the bracket and bear against the edge of the motor cradle. For adjustment, the nuts, Item 124, Plate W.E.-2, which hold the cradle to the lateral adjusting screws, must be slightly loosened to permit the screws to turn and to allow vertical movement under the influence of the Item 126, Plate W.E.-2, screws and adjusting screw locknuts must be backed off several turns. Make the best possible alignment visually and thoroughly tighten the clamps holding the resilient motor mountings in the cradle. Using the motor coupling as an aligning tool, then adjust the screws until the coupling slides freely over both shafts. Tighten the adjusting screw locknuts and the Item 124, Plate W.E.-2, nuts and recheck the adjustment. When the coupling is free with all nuts tightened, align the coupling set screws with the shaft flats and securely tighten them and replace the Item 156, Plate W.E.-2, cover.

With correct alignment the motor will operate with virtually no vibration. Considerable misalignment can be present, however, with little effect on reproducer performance due to the use of the soft molded rubber coupling. Its flexibility also permits the motor to be removed during service operations by undoing its cradle clamps and if the resilient mountings are not too badly swollen from excessive motor oiling, the motor can be replaced in its cradle without necessitating realignment. If desired, the entire motor bracket assembly may be removed from the reproducer without disturbing the rotary stabilizer because two of its mounting holes are slotted and the other is tapped for the third mounting screw. Ordinarily, however, it is simpler to first remove the stabilizer and impedance

drum.

MAINTENANCE OF SOUNDHEAD

Lubrication of the SH-7500 Reproducer is very simple since most of the rotating members are equipped with ball bearings requiring no additional lubrication during the bearing life. Daily, or before each period of operation, apply Motiograph Mechanism Oil to the following points; wipe off any excess:

Oil holes in the sprocket pad rollers.

Sides of projector mechanism drive chain idler roller.

Sides of takeup belt idler rollers.

The oil tubes which carry oil to the drive gears.

Oil cups and gears associated with projector mechanism drives.

Once per week of normal operation apply Motiograph Mechanism Oil to the following points:

The mechanism drive chain.

Oil holes in impedance roller and pad roller bracket arms.

Item 59, Plate W.E.-1, film idler roller (its Oilite bushing needs only infrequent lubrication).

Once per six to eight months of normal operation, oil the motor bearings with a good grade of light automobile oil. Take care that only sufficient oil to saturate the wool packing is applied, for excessive oiling will cause rapid deterioration of the resilinet mountings and of the starting switch inside the motor.

Keep the reproducer clean. Wipe away all excess oil, dirt, and dust before they have a chance to affect operation. It is particularly important to keep all glass surfaces in the optical system free from oil or dust films, for they may cause output signal level and distortion of the reproduced sound. If oily or dirty film is being run, the front lens of the lens tube may need daily, or even more frequent, cleaning and at least once a week all glass surfaces should be cleaned and polished with a soft, lint-free cloth or with lens cleaning tissue.

Great care must be exercised in cleaning the rhodium plated, first-surface mirrors in the Item 33, Plate W.E.-1, lens-mirror assembly. Since the plating, or "silvering" is on the surface facing the light, it may easily be damaged if any sharp implement is used during cleaning. The surface may also be tarnished or damaged by solvents such as acetone, alcohol, carbon tetrachloride, etc. If oil collects in the assembly due to leakage from the projector mechanism above the reproducer, the assembly may be removed and washed thoroughly in gasoline. After complete drying, polish mirrors and replace assembly in the reproducer.

At least once a month of normal operation, and after replacing exciter lamps or photocells, check all optical system adjustments, and make any necessary corrections. Exciter lamps should be replaced when their bulbs blacken sufficiently to cause loss of output signal level or when their filaments show the "glazed" appearance which indicates impending burnout. Photocells usually have very long lives if they are not subjected to excessively high temperatures or mechanical damage. They should be replaced if their sensitivity falls to the point where reproducer outputs cannot be balanced or if they become noisy due to deterioration of internal connections.

The Lens Tube (Item 41, Plate W.E.-1), is properly adjusted for maximum high frequency response during final reproducer testing and, except in the event of extremely rough handling of the reproducer during shipment and installation, or in the event of accidental damage, there should be no need for readjustment until the time for general reproducer overhaul comes.

If transmission tests ("frequency response runs") on the sound system indicate that the high frequency response is below normal, readjustment is in order. The essential equipment consists of a loop of 7000-9000 cycle frequency film, an indicating device such as an output meter connected to the sound system output terminal via a cable long enough to permit it to

be placed near the reproducer, and some kind of a tool to grasp the lens tube. Most service engineers carry a circular clamp-type wrench for the latter purpose but cloth potected pliers will do in an emergency.

Tighten the photocell bracket mounting screws securely and adjust the stud and nut securing the front of the bracket so the light beam from the lens tube clears the end of the film drum by about a thirty second of an inch. If the corprene vibration isolation washers are deteriorated they should be replaced. Remove the sealing compound over the lens tube lock screw and loosen the screw until the lens tube is free. Thread the frequency film into the machine and pull it tight by hand over the film drum in its normal position. Position the lens tube by visual observation so the beam of light on the film sound track is as fine as possible and so that its length is perpendicular to the track axis, in other words, so the beam extends as nearly as can be visually observed straight across the track. Tighten the lock screw just enough to hold the lens tube not quite rigidly in this position.

Install the adjusting wrench on the lens tube (or use pliers) and start the film loop running. Align the sound track with the light beam. Adjust the output meter scale switch and the system gain control to give a low meter reading. If the lens tube is anywhere near the correct position, it should be possible to hear the reproduced frequency, or tone, in the projection room monitor speaker and having the monitor on full is helpful during the adjusting operation. As a matter of fact, in an emergency, lens tubes can be adjusted for reasonably satisfactory high frequency response without auxiliary equipment by positioning them to produce the maximum possible "s" sounds in reproduced speech aurally observed from the monitor speaker or in headphones connected to the amplifier output circuit.

The meter-frequency film adjusting procedure consists of very carefully moving the lens tube toward or away from the film, at the same time rotating it slight-

ly one way or the other, to produce the best possible light beam focus and azimuthal alignment on the moving sound track as evidenced by maximum meter indication. Go through the peak several times to make certain of the setting and then tighten the lock screw securely. It may be sealed with any suitable cement, if desired, to prevent unauthorized adjustments.

Transmission tests, using multi-frequency test films, are the best check on correct lens tube settings; but crisp, clear speech reproduction and natural sounding reproduction of incidental noises and sound effects are likewise an indication of satisfactory adjustment since they are the result of adequate system high frequency response.

All film contacting roller surfaces and the sprocket surfaces should be kept free from dirt and film wax or emulsion accumulations. A stiff brush, such as a toothbrush, dampened with carbon-tetrachloride may be used for this purpose. The felt center section of the impedance roller may be cleaned with a cloth dampened with this solvent; move the cloth against the felt nap. Wipe oil from the rubber motor coupling and resilient motor mountings frequently.

When the felt section of the impedance roller wears nearly to the point where film touches the shoulders of the steel sections it must be replaced. In early reproducer production the felt sections are not generally field replaceable, for the steel and felt sections were gauged in sets. Later impedance roller assemblies (identified by a "V" on the outer bearing retainer cap) have separately gauged components to permit such replacement.

The impedance roller assembly is a fairly delicate piece of mechanism and there is hence considerable justification for returning even the "V" type to the factory when overhaul becomes necessary. The same consideration applies to the impedance drum assembly (Item 38, Plate W.E.-1) and obviously also to the rotary stabilizer assembly (Item 90, Plate W.E.-3) since it is a sealed unit.

THE WESTREX SOUND SYSTEM

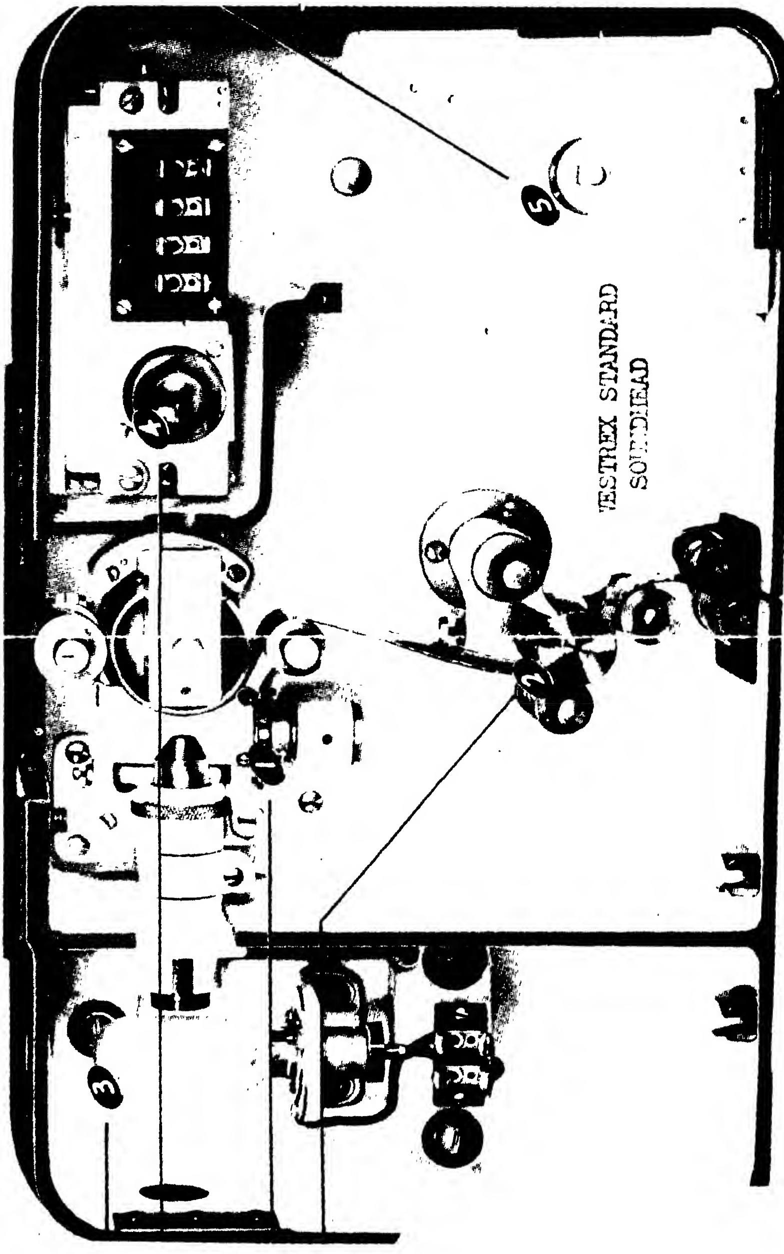
The Western Electric Export Corporation have recently released two new type sound heads, known as the Westrex Standard and Westrex Master. These heads are used in conjunction with the Century Projector.

WESTREX MASTER SYSTEM

The design features unit-assembly, any part may be disassembled by the removal of a few screws, then removed without interference from any neighboring parts. The drive motor is mounted vertically on the non-operating side of the projector, it is easily removable and easy to align. A special brake control is mounted on the operating side of the projector, this operates with a finger-tip pressure to bring the motor and projector mechanism to a quick smooth stop in case of a film-break, or any other emergency. Prefocused, twin exciter lamps are mounted side by side. A simple flip of the finger substitutes one for the other in case of a burn-out. Both lamps are shock mounted and adjusted vertically and laterally to assure perfect alignment with the lens tube.

The new system does not employ the Rotary Stabilizer, a new anti-flutter device being introduced. It involves three steps: (1) isolating the sound mechanism by means of two, free loops of film; (2) imposing a uniform load on the scanning drum, and (3) imparting a uniform drive to the film as it propels the scanning drum.

By delivering film to the sound head through a free loop, disturbances which originate in the projec-


ESTREX STANDARD
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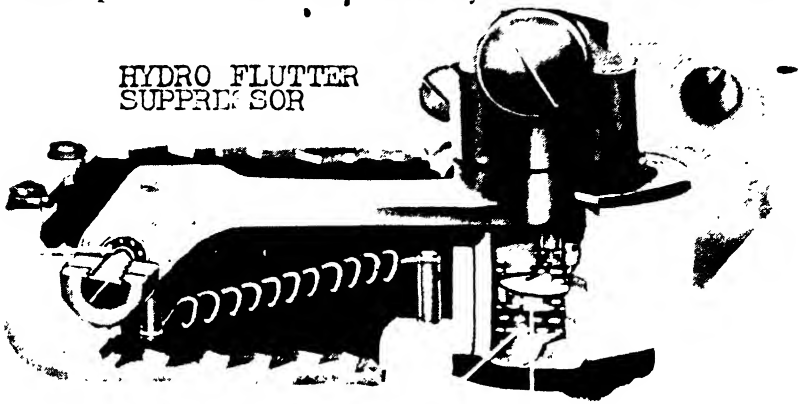
tor are blocked before they can reach the point at which the sound track is scanned. Disturbances in the take-up mechanism are similarly nullified. With this

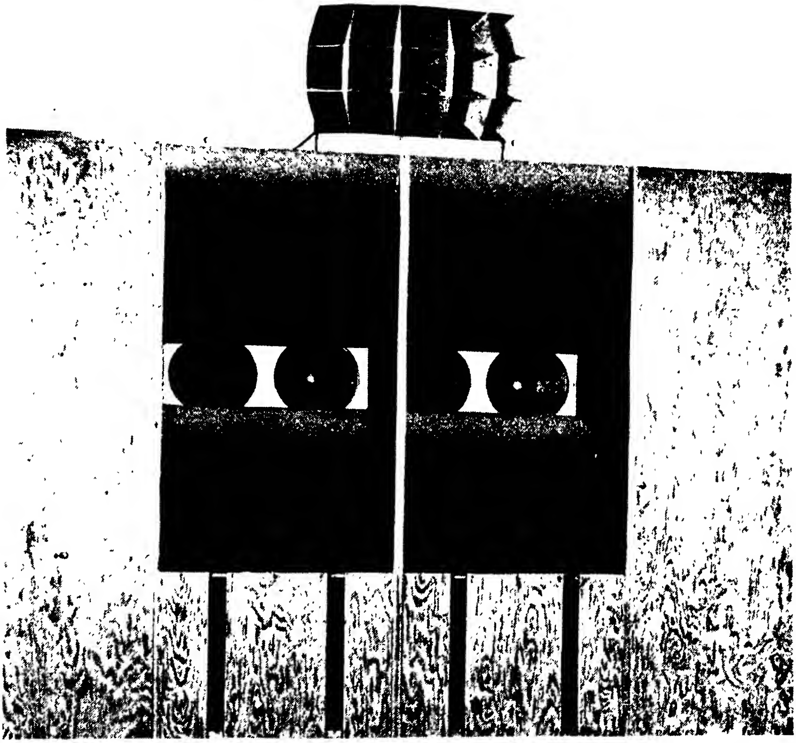


condition provided, if the scanning drum and its associated flywheel can be made to operate under a precisely uniform load, while subject to an ejually uniform driving force, the rotary motion of the scanning drum must, of necessity, be uniform also.

The scanning drum and its flywheel turn on outboard ball bearings. The flywheel carries a heavy ring of copper. The inner face of the flywheel housing supports four permanent magnets so spaced that their fields cut the ring at equal intervals around its circumference. Induced eddy currents provide a load of the required constancy. This load may be increased or decreased by adjustment screws which move the magnets.

Provision for a constant driving force has been met by applying a compensating pressure at some point along the loop of film between the sound sprocket and the scanning drum, to take up the slack continuously, the film moves under constant tension and the driving force it exerts on the drum will be uniform. In the Westrex system, the mechanical filter has been called a "Hydro Flutter Suppressor." In it, a lever arm, pivoted at end by two miniature ball bearings, carries,

at the free end, a pair of small ball races which, as a pad roller, rides against the film. A small adjustable spring causes the pad roller to exert a constant pressure. The lever arm also carries a miniature piston which moves in a cup of special damping fluid. This smooths the action further.



Duophonic loudspeaker combination for Large Theatres.

ADJUSTMENT FOR FILM ALIGNMENT

Another feature is the method of adjusting the film alignment at the scanning point. This is accomplished by a calibrated micrometer which corresponds with the proper setting for a normal print, the projectionist may vary the adjustment over a wide limit to compensate for sound tracks which have been print-

ed off center. A simple twist of the dial restores the adjustment to normal.

OPTICAL ELEMENT

A novel optical element, which in essence is a diffusing lens, is inserted between the objective end of the lens tube and the window of the photocell. Light from either type of sound track (Variable density or variable area) passes through the diffusing element and falls on the sensitive surface of the photocell as a glowing disc of constant area but variable intensity.

Western Electric has taken advantage of the warborn miniature vacuum tubes, to build a small preamplifier, which is mounted right beside the photocell.

AMPLIFIER

Depending upon the tubes used, the amplifier delivers 40 to 50 watts. It operates on the negative feedback principle. Harmonic distortion is less than two percent. This is mounted in a ventilated cabinet, which also has space for a second amplifier unit should this be required as an emergency standby. The chassis fastens to a shelf which swings into a vertical position for servicing and inspection. The amplifier design calls for standard type vacuum tubes. Other features include an operating panel with a control knob for switching the system from film reproduction to turntable or microphone pickup. Another knob controls the volume of the monitor loudspeaker, the power for which is derived from a special, one stage amplifier assembled as a part of the main chassis, and a third knob controls the volume of the turntable and the microphone.

All power conversion from standard A. C. is made electronically by a rectifier of conservative design which delivers energy for the photocell, filaments and plate circuits. A red bullseye, in the cover of the rectifier, lights when the unit is in operation.

WESTREX STANDARD SYSTEM

In principle, the Westrex Standard sound system retains the major improvements of the more elaborate

model but its design has been simplified to meet the requirements of theatres operating on a limited budget.

In the design of the Hydro Flutter Suppressor, two pad rollers, one above and one below the scanning drum, yield to compensate for variations in the pressure of the film. A light spring couples the rollers and their motion is cushioned further by the movements of a small piston in a special damping fluid. Careful laboratory measurements show a flutter content well within the standards set by the Academy of Motion Picture Arts and Sciences.

Threading is simplified by the spacious, well lighted scanning compartment, the absence of extraneous components, (there is only one sprocket and two pad rollers in the path of the film) and a hand wheel mounted directly on the motor shaft.

The exciter lamp is prefocused and shock mounted. It can, however, be adjusted both vertically and horizontally should necessity require.

The amplifier for the Standard system and its electronic power supply are housed in one cabinet. Negative feedback minimizes harmonic distortion to a value of less than 2%. All components likely to be affected by tropical conditions of heat and high humidity have been treated protectively.

The Westrex Standard uses a duplex loudspeaker in which a miniature high frequency multi-cellular horn is mounted coaxially with the low frequency speaker.

FILMOARC 16mm PROJECTOR

The Filmoarc is a sixteen-millometer projector employing a carbon arc as an illuminant instead of the mazda lamp. It has been introduced by the Bell & Howell Company of Chicago, in answer to a growing demand for a 16-mm. projector suitable for use in large auditoriums using a long "throw" from the projection room to the screen, and where a well-lighted and sharply defined projected picture is desired.

INSTALLING THE AMPLIFIER

Grasp the amplifier by the hand holes in the upper portion of either end, and rest it on the platform formed by the middle section of the stand, as is shown in Fig. 473 Center the amplifier on the rubber cushion and you are ready to mount the rectifier.

INSTALLING THE RECTIFIER

First lift the perforated metal cover from the central section of the rectifier and insert the two rectifier tubes into the sockets. After inserting the tubes, grasp the two clips, found on the end of the bronze strip inside the rectifier and slip these over the plate terminals of the tubes. These are the wires emerging from the top of each tube.

The rectifier only, requires 1850 watts, the amplifier about 250 watts. The house line to which it is connected should be fused at 30 amperes.

Lift the rectifier into position, bottom end first, so that the two mounting hooks on the lower sides of the rectifier will engage with the two rubber-covered struts on the stand. Slide the bottom of the rectifier away from you, so that the top will be tilted in and under the amplifier. After it is sitting vertically, move the bottom of it toward you again so as to center the rectifier on the two mounting struts. It

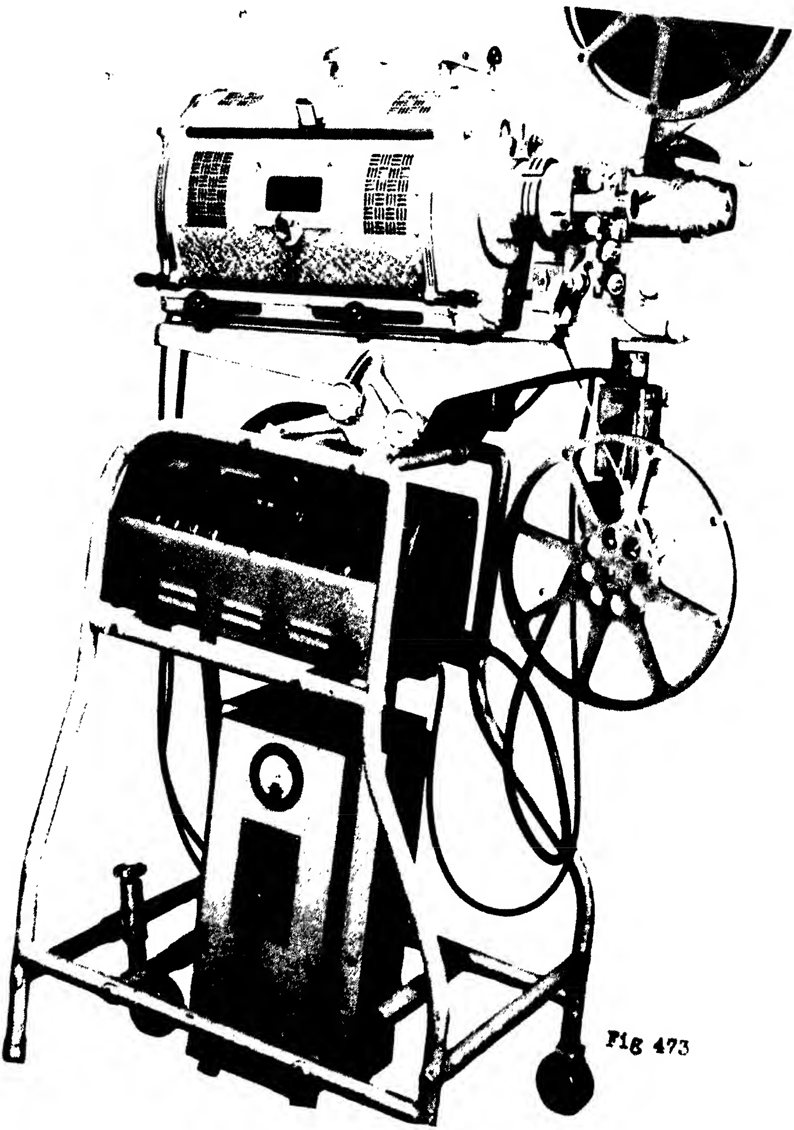


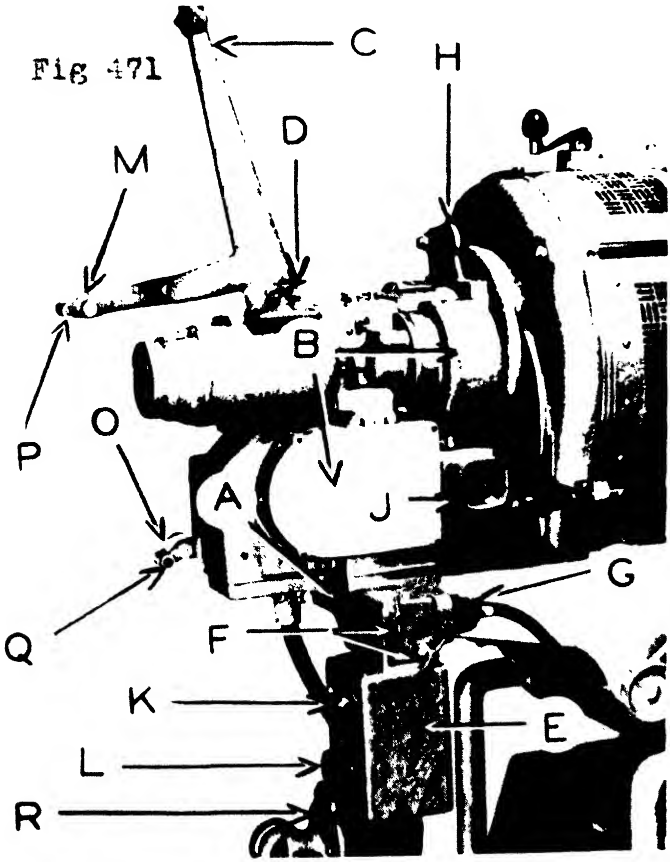
Fig 473

will then be positioned as shown in Fig. 473, directly under the amplifier.

MOUNTING THE ARC-LAMP

Lift the lamp house onto the base of the stand, locating the two runners along the bottom of the lamp into the grooves on either side of the base. Move these two runners so that they are flush in the front. Engage and tighten the two "T" handled screws which are located approximately in the center of the lamp house and beneath the base. Tighten these two screws securely.

Fig 471



MOUNTING THE PROJECTOR HEAD

The projector head assembly consists of a light cone, which is mounted at the rear of the projector drive mechanism—and the sound head. The soundhead and projector head make up one complete unit. Examine the projector mounting base. Beneath this ledge is another "T" headed screw, which holds the projector head on the base.

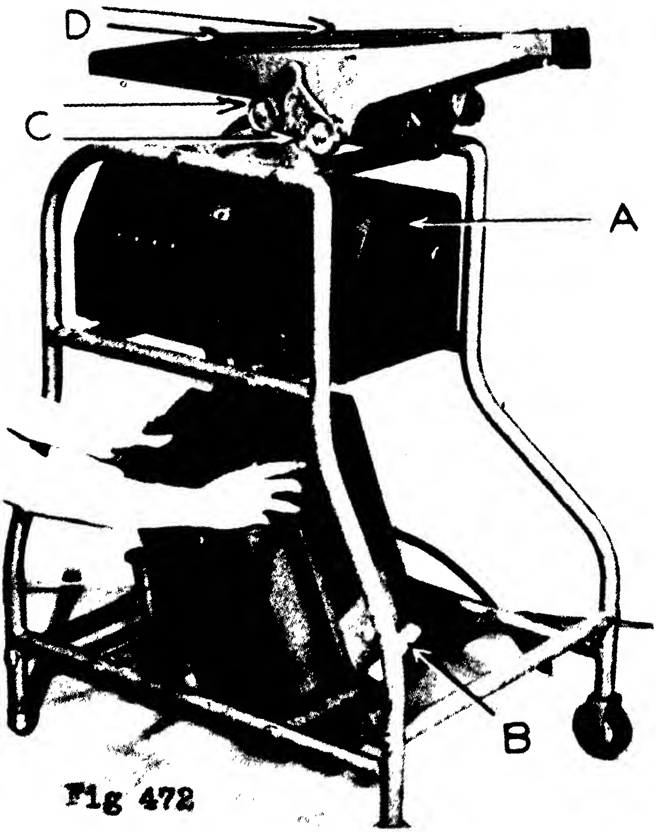


Fig 472

There are two locating pins which align the projector head assembly and the base. Place the projector head on the base so that the two locating pins are engaged in the holes in the base of the soundhead. While holding the head in

place with one hand, use the other hand to tighten the "T" screw beneath the projector base.

Next mount the feed reel arm, the arm holding the upper (feed) reel, by the screw provided, making sure that the rewind pully mechanism faces towards the front of the projector.

MOUNTING THE TAKE-UP AND REWIND ASSEMBLY

This assembly consists of the "rewind take-up" selector switch, the receptacle for the connection of the power to the rewind take-up motor, and the take-up speed adjustment. This assembly is mounted by means of the screws provided. The assembly should be mounted squarely and firmly onto the side of the projector base. Note that there is a small square hole in the front end of this projector base, immediately to the rear of the location on the projector head. A cord, at the end of which is attached a four-pronged receptacle, emerges from the rear of the projector head. This cord and plug assembly should be passed down through the small square hole, and is later attached to the take-up assembly. The major units of the projector are now all in place.

THE HEAT FILTER

Upon examining the cone which connects the light beam from the arc lamp to the projector aperture, you will find a long slot in its top. Into this slot is inserted the heat filter. This filter is made up of a number of segments of glass, so as to permit expansion and contraction. It should be kept clean and out of all draughts and at all times handled with care to avoid breakage.

PHOTOTUBE MOUNTS

Withdraw the phototube mount, by loosening the two screws which will be found in the bottom of the phototube holder. Grasping the cord which emerges from the bottom of the phototube holder, carefully withdraw the mount. See that the phototube is firmly pressed into its socket, and that it is entirely free from finger marks or other dirt. Reinsert it, tightening the two screws to hold it in position. The

phototube faces towards the rear of the machine and the mounting stud is toward the front.

Connect the cable from the bottom of the phototube to the phototube receptacle at the right of the amplifier. It can be placed only in the correct receptacle, as there is only one four-contact receptacle at each end of the amplifier. In running this cable it should be taken around the take-up motor, so that it will not interfere with the take-up reel.

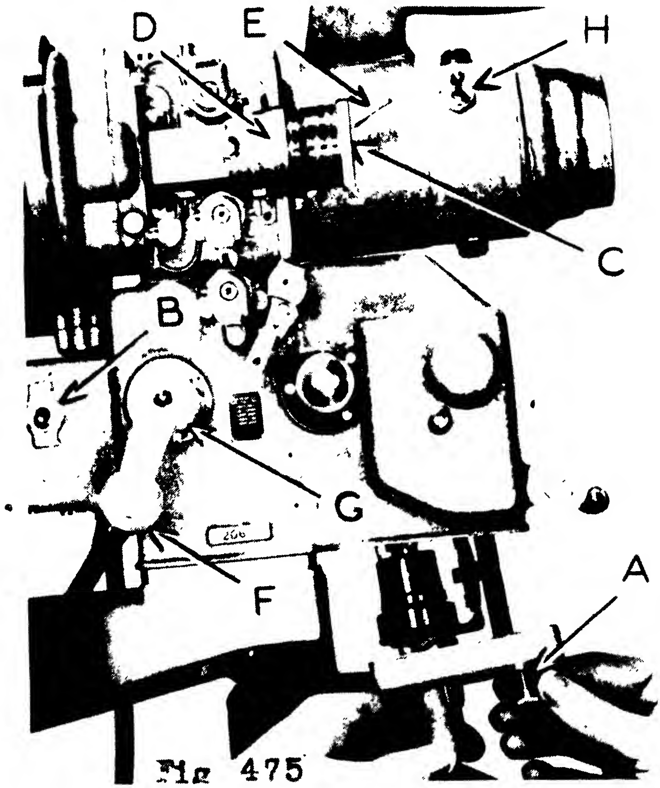


Fig. 475

Locate and install the projector power supply cord. This cord has a six-pronged plug at one end and a four-connection receptacle at the other end. The six-pronged plug is inserted in the six-hole receptacle marked "Projector No. 1" on the right end of the amplifier. The four-pronged recep-

tacle plug is plugged into the power receptacle on, the left side of the projector head. This wire supplies power to the exciter lamp, as well as the 110 volts necessary to operate the projector and take-up motors.

SPEAKER CONNECTION

Plug into the rear of the amplifier, the four-pronged plug found at one end of the speaker cable. Since this projector is intended for use with two speakers, the speaker selector switch, inside the amplifier, should be set at the "Dual-Speaker" position. The speaker end of the cord, having the female receptacle at its extremity, should be connected to the male connection of the receptacle unit in the rear of the auxiliary speaker, the "auxiliary-connector" cord should be plugged in and extended to the receptacle in the rear of the main speaker.

AMPLIFIER LINE CONNECTION

Insert into the two power receptacles in the rear of the amplifier marked "Amplifier-110-volt A.C. only" and "Projector-110-volt A.C. or D.C." the two branches of the "Y" cord supplied with the equipment. The other end of the "Y" cord is to be plugged into the 110-volt A.C. outlet, only after being certain that all switches on the amplifier are in their "off" positions.

CONNECTING THE LAMP TO THE RECTIFIER

From the rear of the arc lamp, emerge two short cords. Each of these has a "twist-lock" connector at its end. One has three terminals on the connector, the other has two terminals. These should be plugged into corresponding receptacles in the rear of the rectifier. They are also color-coded, to avoid confusion. The cord having the red mark should be connected to the receptacles having the red mark. These "twist-lock" plugs are connected by, first inresting into the receptacle as far as they will go, and then giving them a twist, about 1/8 of a turn, to the right. This locks them into position.

INSTALLING THE REFLECTOR MIRROR

Check the amplifier to be certain that the switch in the lower front of the rectifier is pressed down This is the "off" position. Again check the amplifier and see that all of the projector switches are turned off and that the amplifier line switch is off. Plug the power cord from the rectifier into a 110-volt A.C. outlet. With the rectifier switch "off," when the arc-lamp door on the projectionist's side is opened, the interior of the lamp house is automatically illuminated.

Unpack the reflector mirror and install it according to the directions furnished, and after it is correctly installed remove all dirt and finger marks by using a soft cloth and lens cleaning fluid or carbon tetrachloride, and then polishing with lens cleaning tissue.

OBJECTIVE LENS

Large barreled lenses such as the 2-in. F 1.6 Increlite lens, fit the lens carrier on the projector without an adapter. On other lenses of longer or shorter focal lengths and other apertures, where the lens barrel is smaller in diameter, it will be necessary to use an adapter. If it is necessary to make an emergency change of the adapter from one lens to another, we suggest that a mark be placed showing the present location of the adapter on the lens barrel, and when it is replaced on the lens, return it to this setting.

The object of having this adapter ring at a given definite location on the lens barrel is to keep the threads on the adapter in such a location as to permit the proper focusing of the lens.

VENT HOOD AND DAMPER

On top of the lamp house, is a connection which may be used for the installation of a vent pipe if the projector is to be installed in a permanent location. The damper which will be found inside this tube, is intended both to control the smoke and the draft inside the lamp house. If this flue is connected to a pipe and to an outside vent, completely opening the damper might set up a strong air current to cause a noticeable flicker of the arc.

TRIMMING THE CARBONS

Inside the lamphouse, in the compartment to the rear of the reflector mirror mounting, are located two carbon trimming control knobs. One knob adjusts the vertical position of the negative carbon, the other the lateral position of the carbon. The positive carbon vertical and lateral adjustment is governed by the positive carbon guide and by the fact that the positive electrode holder is mounted on a swivel, so that it is free to swing and be guided by the positive carbon guide. The purpose of this adjustment is to assure correct alignment of the tips of the carbons. Rotate the adjustment knob clockwise until the tips of the carbons almost touch, under no consideration leave both carbons in contact with each other, as this would cause a short circuit when you switched on the rectifier.

STRIKING THE ARC

If you have removed the screws holding the lamp door on the left side of the mechanism closed, replace these and see that the left side door of the arc lamp is closed. Check to see that the two carbons are not making contact. Close the door on the operating side. Set the line voltage adjustment switch on the rectifier, at point 3, 4 or 5 (this adjustment is not particularly important at this time, since it will in all probability have to be readjusted as soon as the arc is operating). Snap on the switch to the "on" position. If the connection to the 110-volt A.C. line is complete and correct, the voltage on that line will be indicated on the rectifier line voltmeter. Providing the door of the lamphouse is properly closed, and all connections are properly made, a noise will be heard in the lamphouse. This noise is the operating sound of the carbon feed motor. As soon as possible after the rectifier is turned on, rotate the carbon feed knob, in a clockwise direction until the negative carbon contacts the positive carbon. While doing this, view the arc by looking through the red glass window in the side of the lamp house. Immediately upon establishing contact between the negative and positive carbons, rotate the carbon feed knob in a counter-clockwise direction to draw them apart, until they are separated about 1/4 of an inch. The

arc flame should now, be established between the two electrodes. If, however, the carbons have been moved apart too rapidly the arc flame may not have been established, in which case the process of bringing the carbon tips together and then slowly separating them must be repeated. A little practice will soon assure the operator of the technique, both in striking the arc and in making the necessary adjustments during the running of the show.

With the arc burning and the light projected onto the screen, adjustments will be necessary to both the Reflector Mirror in the lamp house, and to the objective Lens to secure a "clear white field" of light on the screen. It may also be found necessary to readjust the height of the projector stand. This may require tilting up or down or in a lateral position.

FILMOSOUND PROJECTOR

The sixteen-millimeter projector is today being used to very good "box-office" advantage by a number of theater exhibitors, especially in the smaller towns. Equipped with a 16 mm projector in the booth, and a 16 mm camera, these exhibitors make a practice of "shooting" all local events of interest and combining these shots into a local news-reel, which they show regularly every week. Motion pictures are made of anything of local interest, weddings, high school graduations, local football and baseball games, outings of local organizations such as the Rotary and Lions Clubs, and so on.

The showing of these local news-reels are looked forward to with great interest by the townsfolk, and the interest worked up in the photographing of the local events has proved a good advertisement for the theater.

Fig. 505 shows the relative positions of the units required for Filmosound projection, as well as the electrical connections, for operating on 110-volt 50 or 60 cycle alternating current. The same arrangement of components is used for the special Filmosound for 25

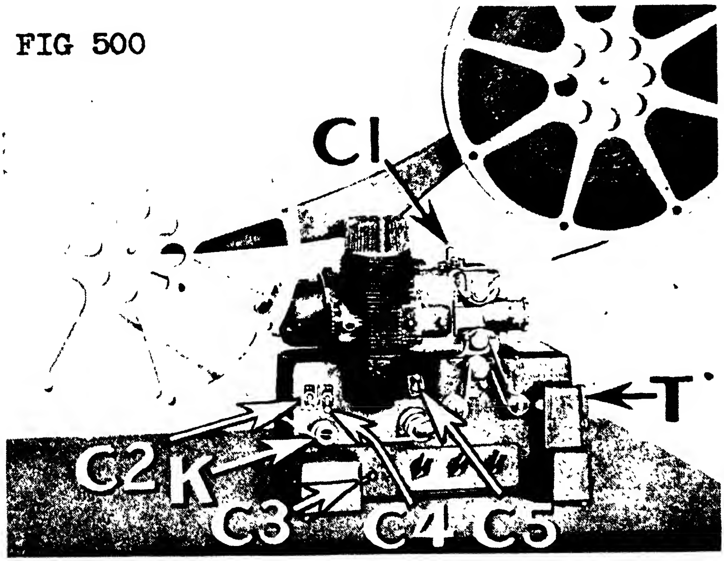
to 60 cycle 110-volt operation.

An ordinary ten-ampere fuse in the lighting circuit is adequate if you can be sure that the line is not and will not be otherwise loaded.

Turn the volume control to the extreme low position, and make sure that the line current switch is in "OFF" position.

Plug the four-contact male plug of the speaker cable (Cord B, Fig. 505) firmly into the receptacle in the projector, and the four-contact female plug of this cable into the receptacle at the rear of the speaker. The connections are such that this can be done only correctly.

FIG 500



Connect the ten-foot "Y" cord to a convenient 110-volt 50 or 60 cycle A. C. outlet and to the marked projector and amplifier receptacles in the left side of the base.

Remove from the case (into which the speaker is built) all loose material; it might rattle with the reproduced sound.

Place the speaker as near as possible to the center of the screen and above the floor, but not so high as to interfere with the picture. Do not place the screen or other obstruction to the sound in front of or within 18 inches of the back of the speaker. Remove the small door covering the speaker grill.

Before threading, start the projector with the line current switch (C3 in Fig. 500), and turn on the lamp with the lamp switch (C4 in Fig. 500). Move the projector as necessary to get the picture properly placed

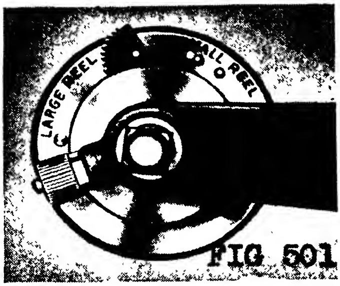


FIG 501

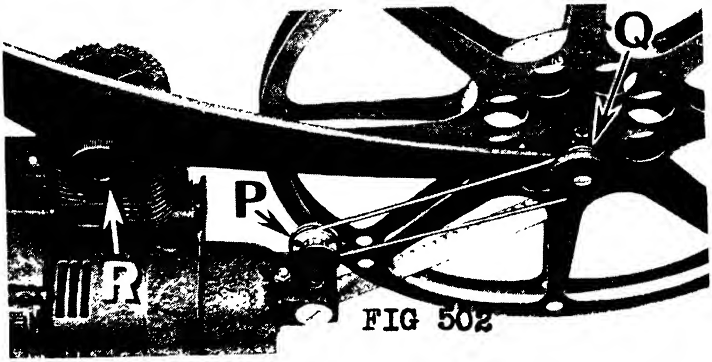


FIG 502

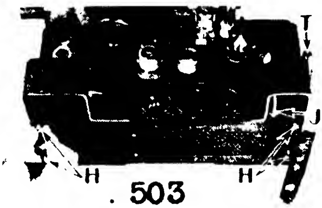
on the screen. An elevator, controlled by the knob on the base front, permits tilting the machine to raise the picture. Turn the projection lens to the left or right as necessary to bring the edges of the illuminated area into sharp focus. Then turn off both lamp and line switches.

THREADING THE FILM

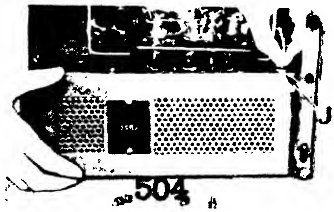
Figs. 500 and 506 clearly illustrate the path of the film through the projector and the sound head mechanism.

Snap the loaded film reel in place on the feed (front) spindle so that the film comes off the reel as shown in Fig. 500. The sound track should be on the left, when looking at the machine from behind. Unwind about 3 feet of film.

Open the projector's film gate by raising the film gate lever (A, Fig. 507).



503



504

Open the guards G1 and G2 of the first and second sprockets by pressing down and up, respectively, as in Fig. 508.

Slip the film beneath the upper sprocket S1, as in Fig. 509. See that the film perforations engage with the sprocket teeth. Then press up on the sprocket guard G1 to close it, thus locking the film on the sprocket.

Insert the film into the film channel, as in Fig. 510, leaving a loop of film above the film gate, as shown.

This loop should be large enough so that eight perforations are visible between the sprocket and the top of the film gate.

Leaving another loop (this one showing seven perforations) below the film gate, slip the film over the second sprocket S2, as in Fig. 511. See that the film perforations engage with the sprocket teeth, and then close the sprocket guard G2.

Close the film gate by pushing down on the film gate lever (A, Fig. 507).

This concludes the threading of the projector itself. Test the correctness of this part of the operation by moving the clutch (C1 in Fig. 500) back as far as possible and by giving the hand setting knob (B, Fig. 507) a few turns to see that the film moves through the mechanism.

As in Fig. 512, lead the film to your left of the shrinkage compensating spring roller F and around the sound drum D.

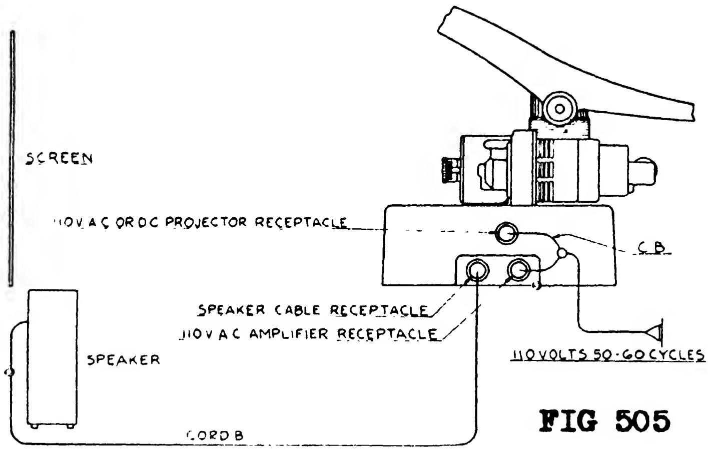
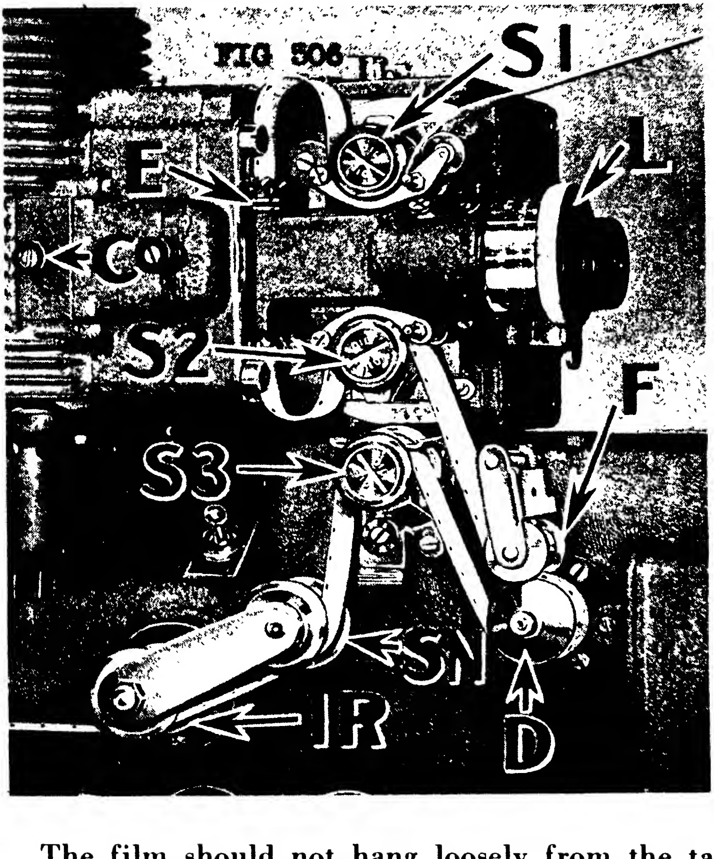


FIG 505

Next lead the film to the third sprocket S3. Raise and hold open this sprocket's guard G3, as in Fig. 513. (It is convenient to use the middle finger of the right hand to raise this guard), and insert the film over the sprocket, but not in quite so far that the sprocket teeth engage the perforations. Draw the film up snugly, so that the spring roller F is swung well to the right, as shown. Then back up the film (loosening it) just enough to engage the perforations with the first available sprocket teeth. Then release the sprocket guard G3. When this operation has been completed correctly, the appearance will be as in Fig. 514. Note particularly the position of the spring roller F. Only when

threading is correct will this roller be in the position shown in Fig. 514.

Next pass the film beneath the two rollers (SN and IR) of the snubber, as in Fig. 506, and beneath the rearmost roller K, Fig. 500. Thence lead and attach the film to the hub of an empty reel on the rear spindle of the reel arm, as shown in Fig. 500.



The film should not hang loosely from the take-up reel. If it does, turn the take-up reel so as to take up the slack. Then, holding the reel from turning, pull the upper part of the spring belt toward the rear until the reel no longer tends to unwind.

Check back over threading to make sure that the loops are correct, that all sprocket teeth are properly engaged in film perforations and that the sprocket guards G1 and G2, and the film gate, are closed.

Check the tension adjustment on the take-up reel arm (see Fig. 501) and set for the take-up reel size.

Be sure that the amplifier is turned on, by means of the volume control knob, and that the "Direction" switch (C2 in Fig. 500) is set to "Forward."

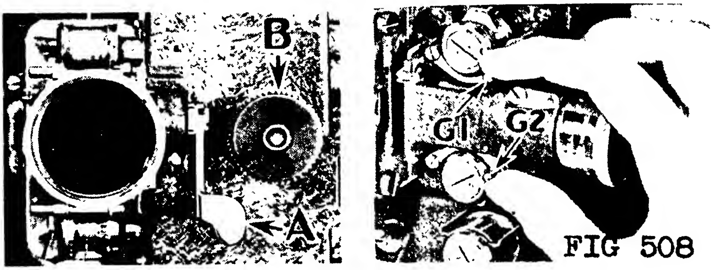


FIG 508

When running sound film, be sure the "Speed" switch (C5 in Fig. 500) is set to "Sound."

Push the clutch forward. Turn lamp on. Then start the projector with the line switch and run for two seconds. Stop the projector, check the loops, and make sure that the film is running through the machine correctly and that the loop around the sound drum has remained correct.

After you have become practiced at threading the film through the mechanism, turn on the amplifier before threading. This will allow the amplifier tubes to warm up to the proper operating temperature, so that sound projection can be started as soon as threading is completed.

PROJECTING SOUND FILM

Start the Filmosound motor by moving the line switch to "ON."

Turn on the lamp with the lamp switch.

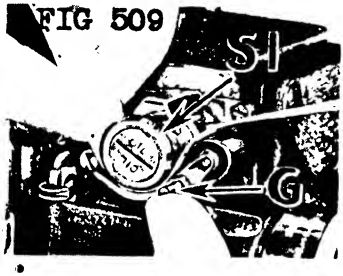
Turn the volume control in a clockwise direction until sufficient volume is obtained.

For films in which the sound is primarily speech, the tone control should generally be turned towards the high position. The low position usually results in more pleasing reproduction of music.

PROJECTING SILENT FILM

To project silent film, thread the machine in the usual way. Set the speed control switch at "Silent." Do not turn on the amplifier unless oral comments are to be made through the speaker by means of a microphone. Even when so using the amplifier, leave the film volume control at its minimum volume position.

FIG 509



STOPPING

For a "still" picture, move the clutch (Cl in Fig. 500) back as far as possible. If picture does not appear, turn knob B, Fig. 507.

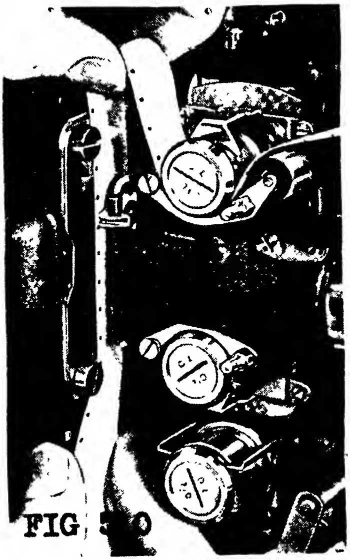
Just before the end of the final scene or title appears on the screen, retard the volume control, and turn off the projection lamp by means of the lamp switch to prevent a white light on the screen. Let the film continue to run through the mechanism until it is all wound onto the take-up reel. Then stop the projector by throwing the line switch to "OFF" position. Unless another reel is to be threaded and shown at once, turn the amplifier off to save the tubes from unnecessary use.

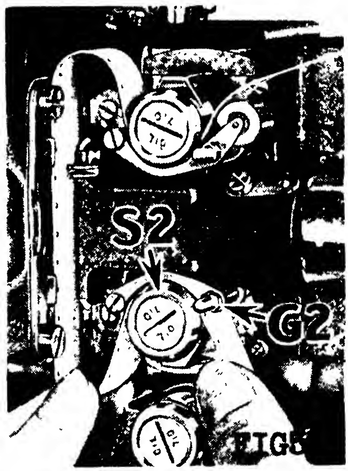
REVERSING

Turn the volume control until sound is inaudible. Then stop the forward motion of the film either by

disengaging the clutch, or by turning off the projector motor. After the mechanism has stopped operating, turn the direction switch to reverse. To change direction, always stop the projector before reversing the direction. Lamp may be on or off, as desired.

See that the lamp switch is at "Off," the speed switch at "sound," and the direction switch at "Forward." Throw the line switch "On." The film will be rewound rapidly by the projector motor. When all has passed to reel M, turn the line switch off.





D. C. OPERATION

To operate the Filmosound on direct current, a high quality D. C. to A. C. converter having a capacity of 75 or 80 watts is needed. The output from the converter is used only for the amplifier. The projector motor and lamp operate from the direct-current line. Fig. 517 illustrates the proper connections. One side of the "Y" cord is plugged into the converter, while the other side is connected to the projector receptacle. The A. C. output of the converter is fed to the amplifier

receptacle. When these connections have been made, the operation is the same as for A. C.

MAINTENANCE

Occasionally the aperture should be cleaned by removing the lens from its carrier and inserting the aperture brush, supplied with the projector, through the opening. Carefully brush all corners and edges of the aperture to remove the dust, which causes dark, fuzzy edges on the projected pictures.

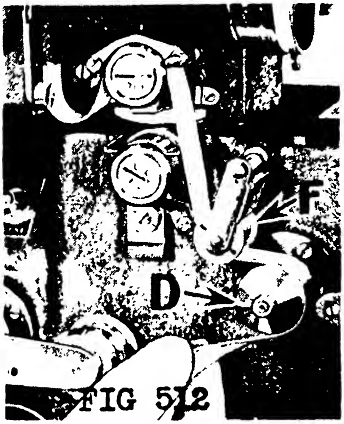


FIG 512

Open the film gate as for threading the projector and, with a soft lintless cloth, remove any dust and dirt which may have collected in the film channel. If rubbing with a dry cloth does not remove the dirt, moisten the cloth with alcohol. Then, with the little finger, make sure that all the small rollers are revolving freely.

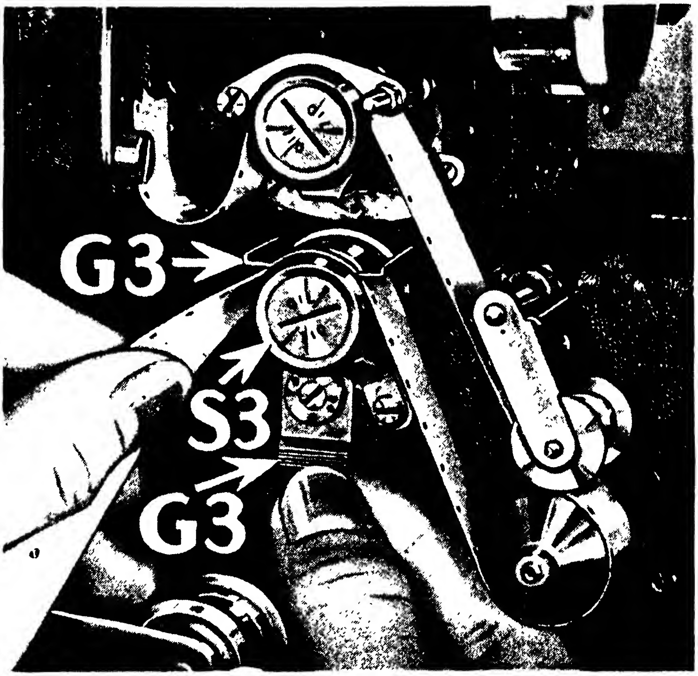
Clean all other film handling parts — sprockets, sound drum, and rollers — in the same way. Never use any metallic instrument for cleaning any surface over which the film passes. The projector should not be running while these cleaning operations are done.

The projection lens should be kept scrupulously clean and free from dirt and oil.

The condenser is removed from the projector by

pulling on its holder handle C, Fig 506. It should be cleaned frequently with the same materials as used for the lens.

Never attempt to remove or adjust the lens of the sound optical system, as this requires special training and equipment. This lens, with one face exposed within the exciter lamp compartment and the other exposed



outside, toward the sound drum, should be cleaned occasionally, as should the mirror which can be seen by looking down behind the sound drum from in front of and above the Filmosound. Remove the exciter lamp compartment cover and wipe the lens at both ends, and the mirror, with lens cleaning tissue wrapped around a tooth pick.

To replace a projector lamp, unscrew the cap at the bottom of the lamphouse, allowing the lamp to slide out into the hands. Then insert the new lamp

after having removed any finger marks from it, and revolve it until the tongue on the centering ring of the lamp settles in the centering slot at the front in the bottom of the lamphouse. Replace the screw cap, making sure that it screws squarely and tightly to lock the lamp in proper position.

Never attempt to change a lamp with the current on. Lamps are required to burn with tip up, and the machine should not be turned upside down or laid on its side while the lamp is burning.

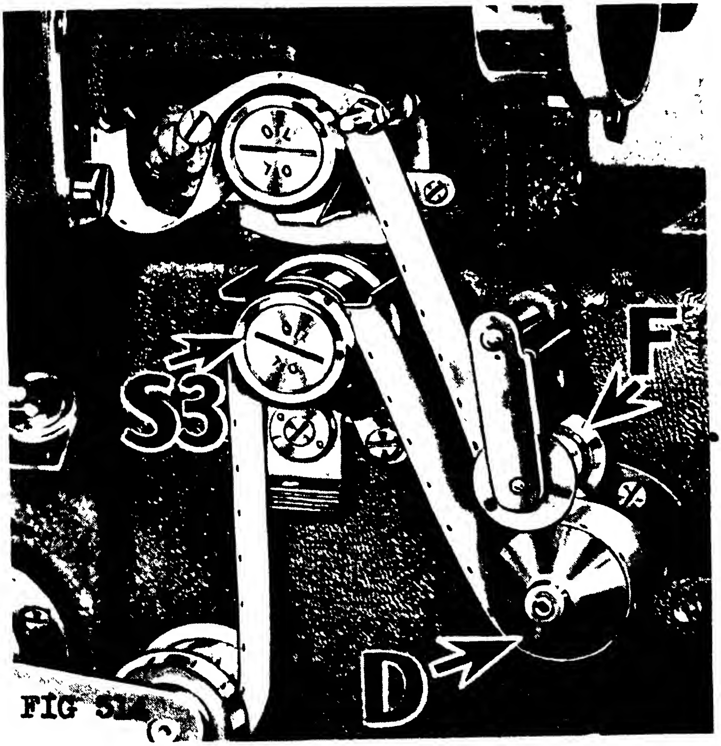


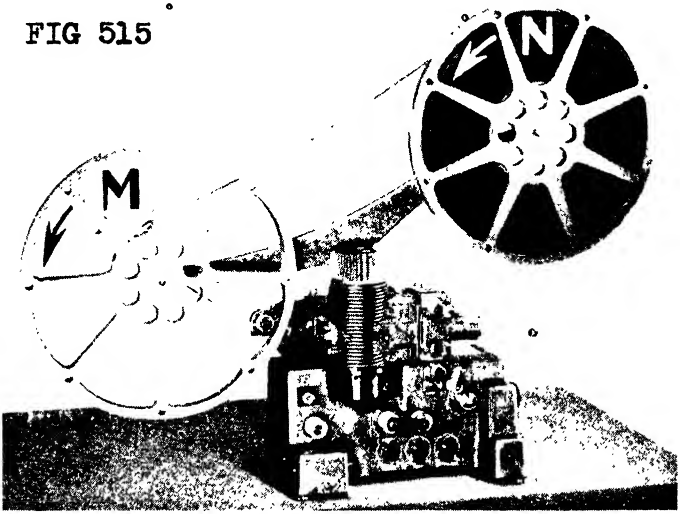
FIG 51

The exciter lamp is beneath a three-sided metal cover at the front right-hand corner of the base. Unscrew the thumb nut (on the front) and remove the cover of the exciter lamp compartment. Press the

lamp down, turn it counter-clockwise slightly, and lift it out. It is not necessary to loosen the set screw which holds the exciter lamp socket in place.

Ordinarily, no adjustment is required when an exciter lamp is replaced. However, if it appears necessary, adjustment is easily accomplished by loosening the two set screws on the lamp socket. Care should be taken not to rotate the socket while this adjustment is being made, as the filament plane must face the lens. Move the lamp socket carefully until, when view-

FIG 515



ed directly across the top of the filament, this top of the filament lines up precisely with the inscribed line immediately to the rear of the exciter lamp. Only a turn or two is necessary to loosen the two screws, and they should not be re-tightened too tightly, but just enough to hold the socket securely.

A two-ampere fuse is provided in the amplifier, and should be checken immediately if the amplifier tubes fail to light. This fuse will burn out if direct current is fed into the amplifier current supply receptacle. The fuse cover, clearly marked, is on the

bottom of the amplifier base. Always disconnect the line cords before removing the fuse cover.

TROUBLES—WILL NOT OPERATE

(a)—Current supply cord not making proper contact with house power outlet.

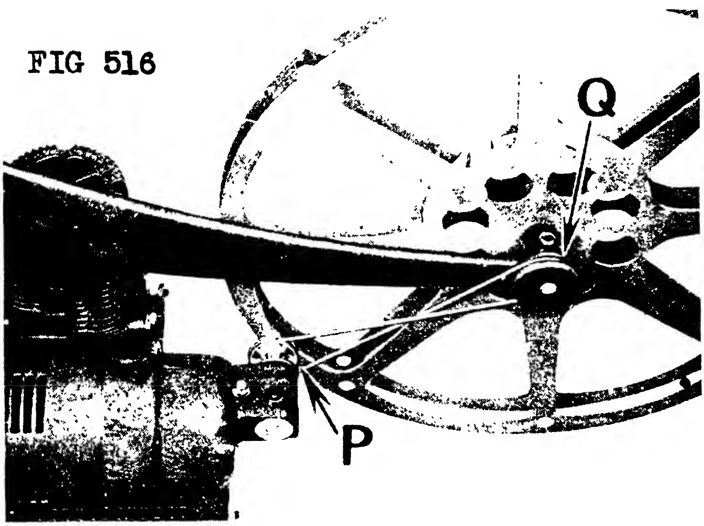
(b)—No current at the house outlet. Test with ordinary lamp.

NO SOUND

A.—If the exciter lamp fails to light, the absence of sound may be caused by:

(a)—Speaker cord not connected at both ends.

FIG 516



(b)—Amplifier turned off.

(c)—Fuse blown out.

(d)—Tubes in the wrong sockets, or one or more tubes not in its socket.

(e)—Burned out exciter lamp or defective 5Z4 or 6F6 tube.

B.—Should no sound be produced even though the exciter lamp lights, the trouble may be caused by:

(a)—Volume control not advanced sufficiently far toward the "high" position.

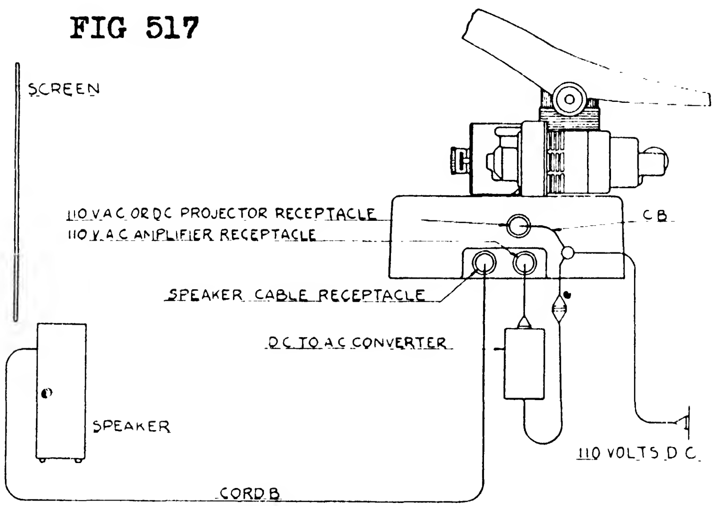
(b)—Film incorrectly threaded.

(c)—Grid clip not attached to the cap on the 6J7 tube in the sound head.

(d)—Dirt, dust, oil, or other foreign matter obstructing the sound optical system. Turn off the amplifier and clean the sound optical system.

(e)—Absence or defectiveness of sound record on the film. To prove that the trouble is not with the Filmosound, remove the film and turn on the amplifier. Turn the volume control knob to the "high" position. Pass a card swiftly back and forth between the

FIG 517



sound lens and the sound drum. If a loud "thumping" sound is heard from the speaker, the Filmosound itself is shown to be operating properly, and the lack of sound is undoubtedly due to the film.

(f)—Defective tubes. Have all tubes tested and replace any which prove to be defective.

INADEQUATE VOLUME

(a)—Volume control not advanced far enough.

(b)—Poorly made or dirty film. Compare resulting sound with that from a film known to be clean

and well made.

(c)—Dirt, oil, or other foreign matter partially obstructing the sound optical system.

(d)—Defective tubes. Have all tubes tested and replace any which prove to be defective.

(e)—Defective, or dirty, or poorly adjusted exciter lamp.

(f)—Excessively low line voltage.

UNSATISFACTORY SOUND QUALITY

(a)—"Speed" switch is set in "Silent" position.

(b)—Dirty, oily, scratched, or poorly recorded or printed film. Compare results with those of a film known to be satisfactory.

(c)—Incorrect film threading.

(d)—Sound optical system partly obstructed.

(e)—Defective tubes. Have them all tested and replace as necessary.

NOISES

Are usually traceable to defective tubes. Failure to fasten the amplifier in the base firmly may cause noises, too, as may the phototube or 6J7 tube or a loose 6J7 grid clip.

A. C. hum can sometimes be reduced by reversing the A. C. plug at the supply socket.

Static-like sounds may occur if the tube base prongs are dirty. Clean them with 00 sandpaper and wipe them well.

NO PICTURE

Should projection lamp not light when the lamp switch is "on" and the projector motor running, the lamp is burned out. Replace it.

INSUFFICIENT PICTURE BRILLIANCY

(a)—Extraneous light falling upon the projection screen.

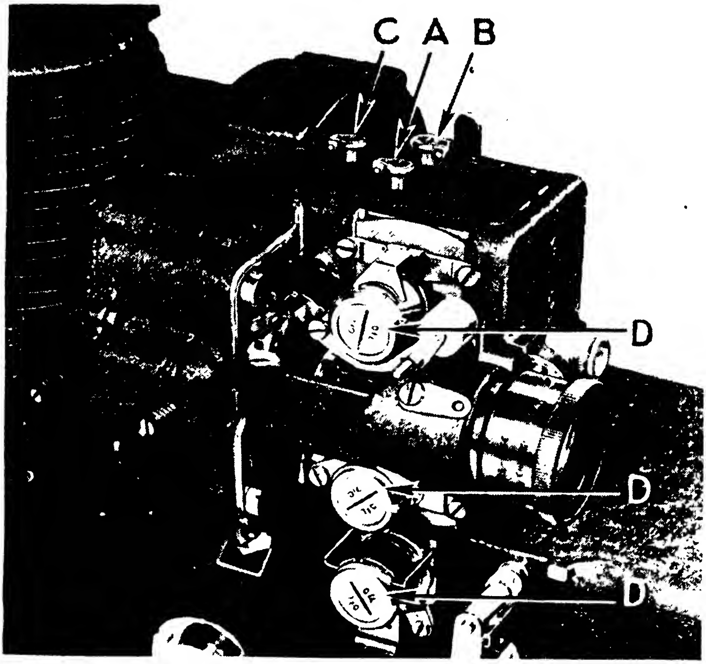
(b)—Blackened projection lamp. Effective lamp life may terminate before the lamp actually burns out. Remove the lamp and replace if necessary.

(c)—Dirty projection lens, condenser, or lamp. Clean as directed.

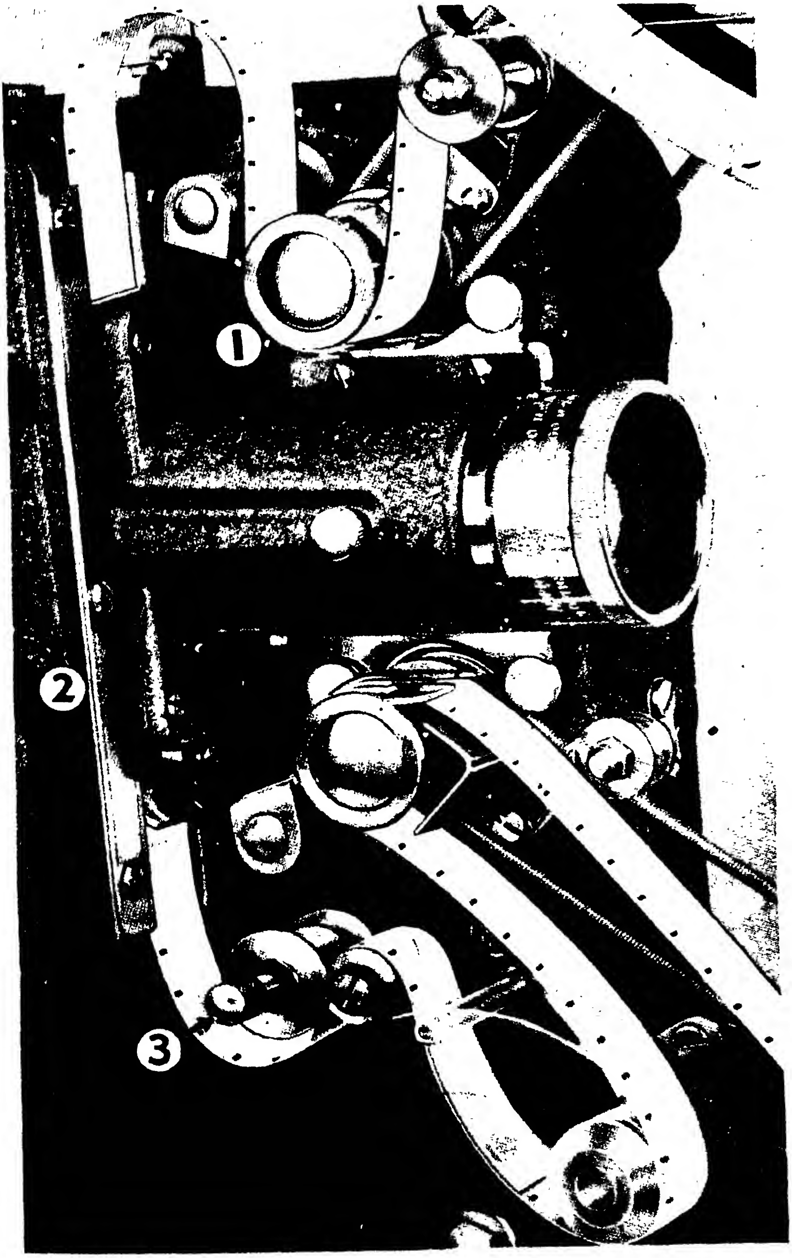
(d)—Abnormally low line voltage.

BLURRED, STREAKED PICTURES

Caused by loss of the loop below the projector aperture. Stop machine and rethread correctly.



Points requiring lubrication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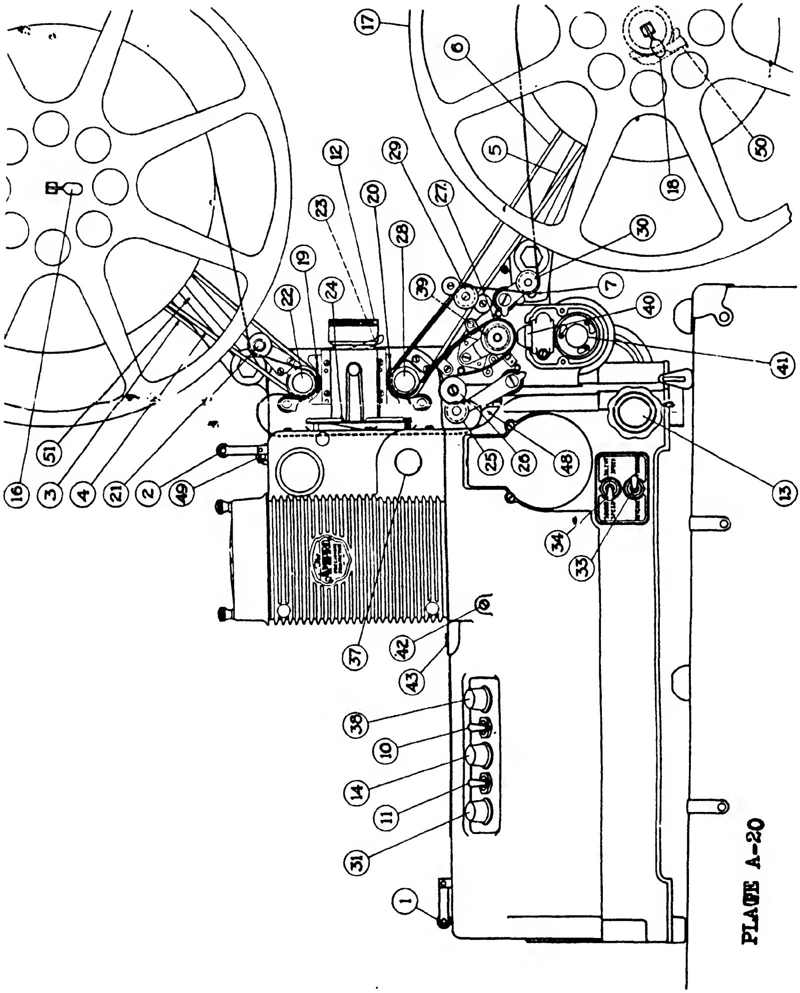
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PLATE A-20

AMPROSOUND PREMIER-10 PROJECTOR

The Amprosound Projector is a product of the Ampro Corporation of Chicago, and a member of General Precision Equipment Corporation of New York. This is a portable 16 mm projector, equipped with reel arms to accommodate 2000 reels of film. The intermittent movement is of the "triple claw type" and engages three film sprocket holes simultaneously. This is an advantage when running film with weak or torn sprocket holes.

The projector uses the standard type of prefocused lamps ranging up to 1,000 watts. The lens system comprises a 2-inch F 1.6, and this can be easily replaced by lenses of other focal lengths if necessary, the Aspheric condenser lens is of heat resisting optical glass. The projector operates on 50-60 cycles A. C. current. The motor is of the universal type and may be used on either A. C. or D. C.

SETTING UP THE EQUIPMENT

Remove the top section of the projector carrying case, lift projector by the carrying handles (1 and 2, Plate A-20). Place the projector either on the inverted bottom half of the carrying cose or on a table.

If the power supply is 100-120 volts, 50-60 cycle A. C., connect the line cord from the power outlet to the Line Receptacle (8, Plate A-21). The converter plug (44, Plate A-21) should be plugged into the Converter Receptacle (45, Plate A-21). If the power supply is 100-125 volts, D. C., it will be necessary to have a converter having a capacity of 750-100 watts and an output voltage of 100-120 volts, 50-60 cycle A. C.

Fold the reel arm (51, Plate A-20) into position and fold the take-up reel arm (5, Plate A-20) into place. If a 400 foot take-up reel is to be used, place the Reel Arm Lock Pin (7, Plate A-20) in the upper hole in the reel arm. If a larger reel should be used, place the Reel Arm Lock Pin (7, Plate A-20) in the lower hole of the reel arm. Check to see that the Belt Shifter (50, Plate A-20) is turned clockwise as far as possible.

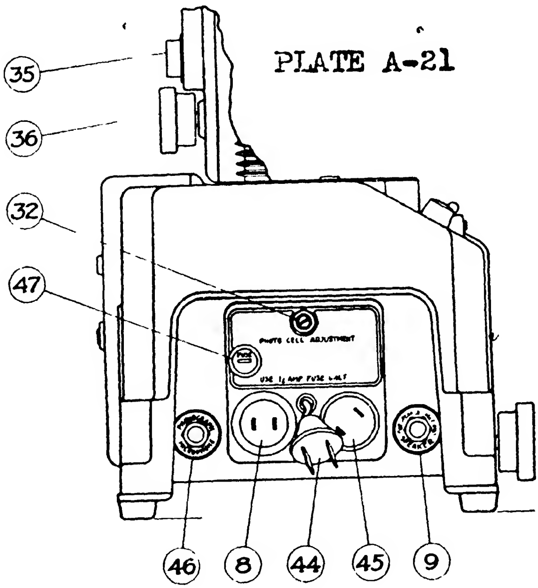


PLATE A-21

Throw the Starting Switch (10, Plate A-20) to "Starting" position. Throw Speed Switch (34, Plate A-20) to either "sound" or "silent" speed position, as desired for the type of film to be shown. Next turn on the lamp switch (11, Plate A-20) and focus image of the gate aperture on the screen by turning the Projection Lens (12, Plate A-20). Turn Tilt Adjusting Knob (13, Plate A-20) to elevate the projector so that the

projected picture will be correctly framed and positioned on the screen. Place reel of film (15, Plate A-20) on feed spindle and fold over Feed Reel Lock (16, Plate A-20). Place an empty reel (17, Plate A-20) on the take-up spindle and fold over the Take-Up Reel Lock (18, Plate A-20).

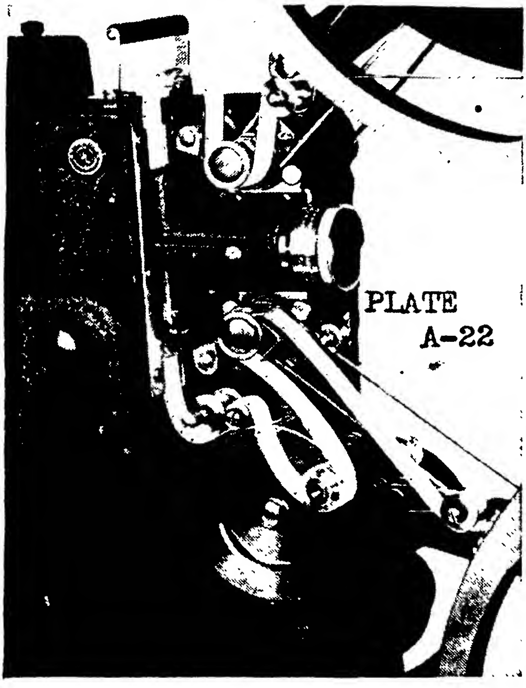
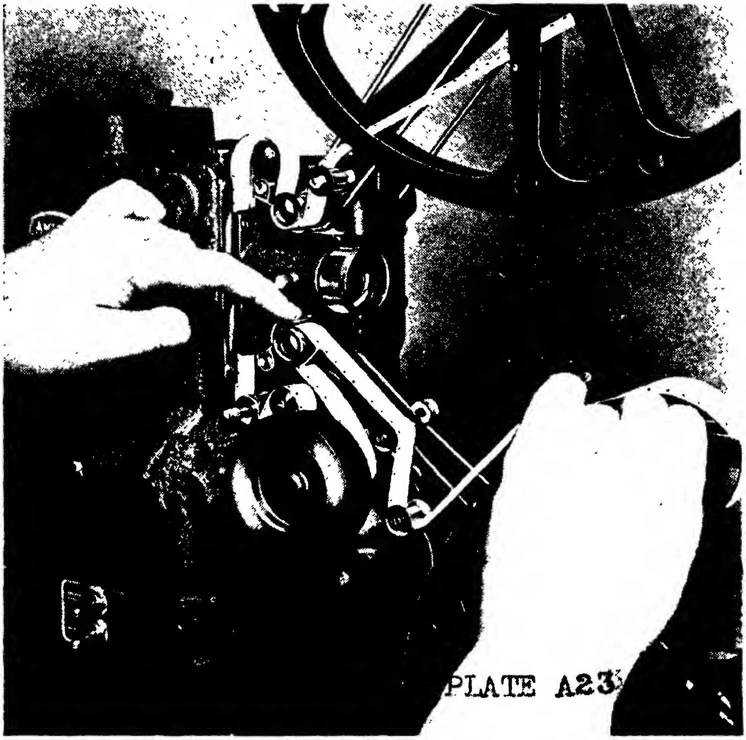


PLATE A-22

Remove front and rear covers from the speaker case and connect one end of the speaker cord to the jack in the back of the speaker. Place the speaker near the screen and lay the speaker cord where it will not be walked on, or otherwise moved. Connect free end of speaker cord to Speaker Jack (9, Plate A-21) in the rear of the amplifier.

Turn on the Projector Volume Control Knob (14,

Plate A-20) and the Microphone Volume Control Knob (38, Plate A-20). After amplifier is warmed up, advance the Photocell Adjustment (32, Plate A-21) until a hiss is heard from the speaker. This adjustment should be made with the projector volume control set at "normal" position. Turn Photocell Adjustment (32, Plate A-21) counter-clockwise until the hiss is barely audible. If there is a very loud hiss or a popping noise



when the Projector Volume Control Knob (14, Plate A-20) is turned either to the maximum or minimum position, then turn Photocell Adjustment (32, Plate A-21) counter-clockwise to correct the condition.

THREADING THE PROJECTOR

The method of threading the projector can be seen by referring to Plates A-22, A-23 and A-24.

PLATE A-24

First unwind about three feet of film, open Sprocket Shoes (19 and 20, Plate A-20) by pressing the shoes toward each other. Also open projector gate by moving the Lens Holder Lever (23, Plate A-20) upward.

Thread film over Film Feed Guide Roller (21, Plate A-20), then around Feed Sprocket Shoe (19, Plate A-20). Place the film in film gate, as shown in Plate 24, making sure that the film lies in the grooves in the aperture plate. Now move Pressure Roller (25, Plate

A-20) to the back position and thread pressure roller and then up between pressure roller and Tension Roller (26, Plate A-20), also see Plate 23. Also thread film around lower guideway and around Sound Drum (27, Plate A-20) and Plate 23. Thread film over upper guideway and around Take-Up Sprocket (28, Plate A-20), seeing that the film perforations engage with the sprocket teeth, then close Take-Up Sprocket Shoe (20, Plate A-20).

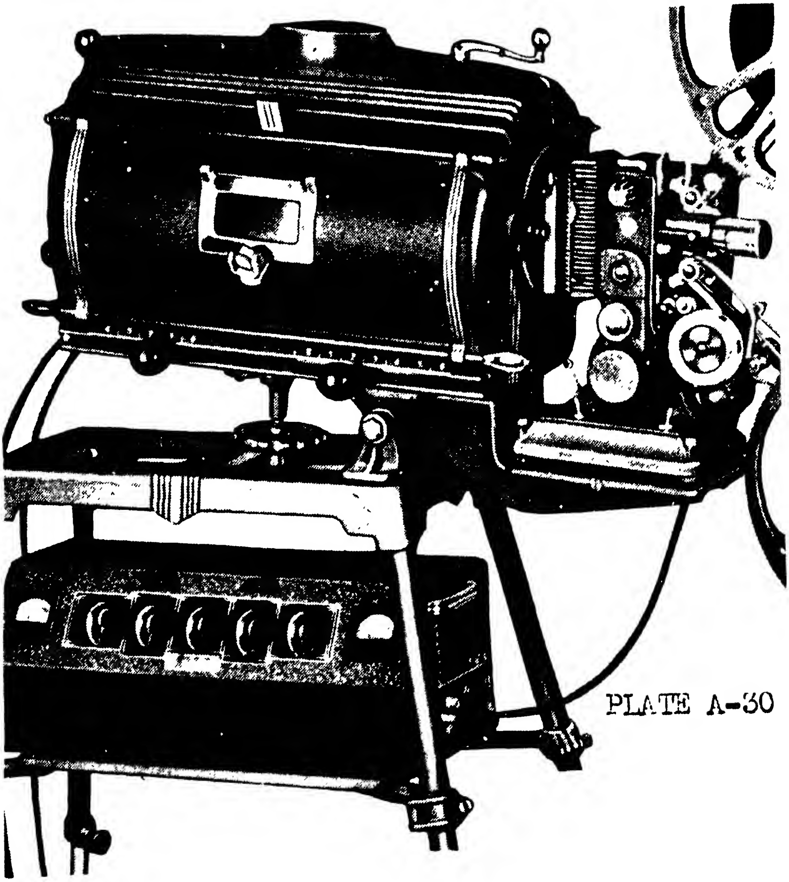


PLATE A-30

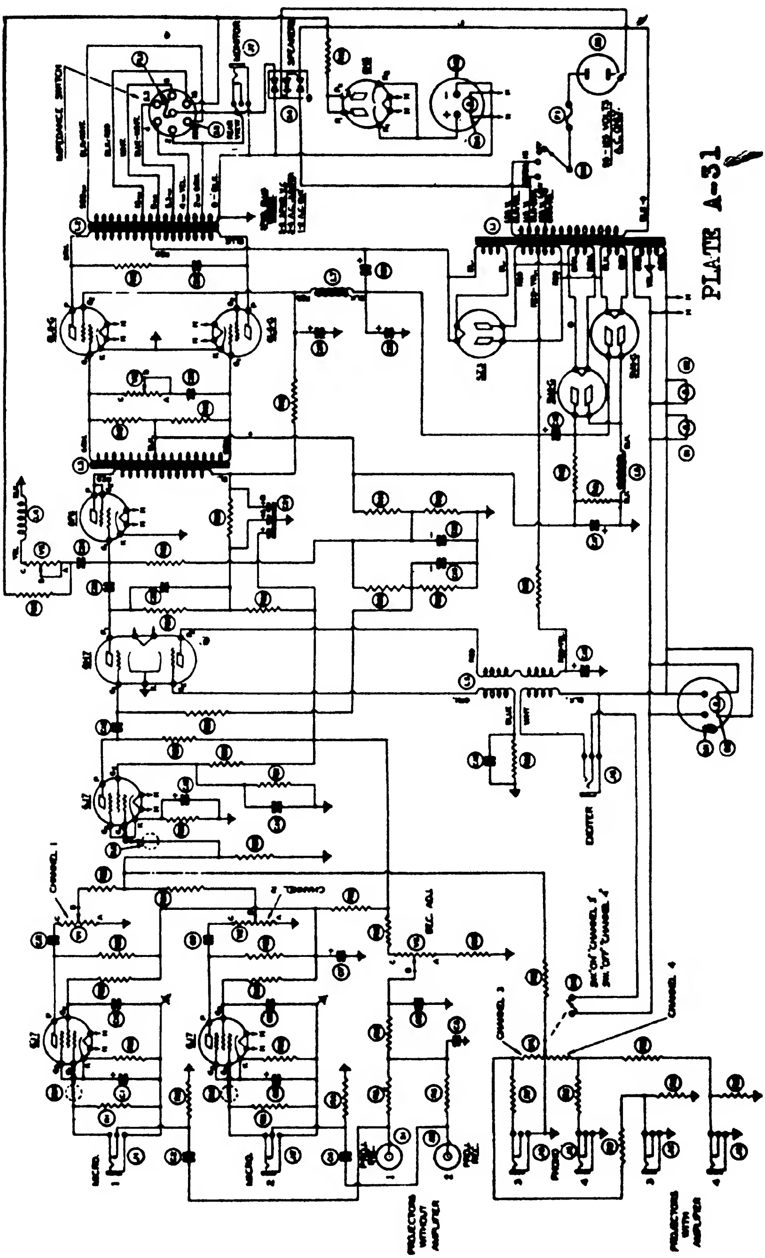

IMPEDANCE SWITCH
MONITOR
SPEAKERS
EXCITER
CHANNEL 1
CHANNEL 2
CHANNEL 3
CHANNEL 4
MICRO.
PROJECTORS WITHOUT AMPLIFIER
PROJECTORS WITH AMPLIFIER

PLATE A-31

Now thread over the Film Take-Up Guide Roller (29, Plate A-20) and under Film Tension Equalizer Roller (30, Plate A-20), engage the loose end of the film in slot in Take-Up Reel (17, Plate A-20) and turn the reel by hand, clockwise to take up the slack in the film.

Pull upward on the film at point where it enters film gate, in order to take up any slack, then push down on Lens Holder Lever (23, Plate A-20) thereby closing film gate. Then move Pressure Roller (25, Plate A-20) to the front position thereby holding film between pressure and tension rollers.

Check the threading, then turn Shutter Adjusting Knob (36, Plate A-21) and watch the movement of the film.

PROJECTING SOUND PICTURES

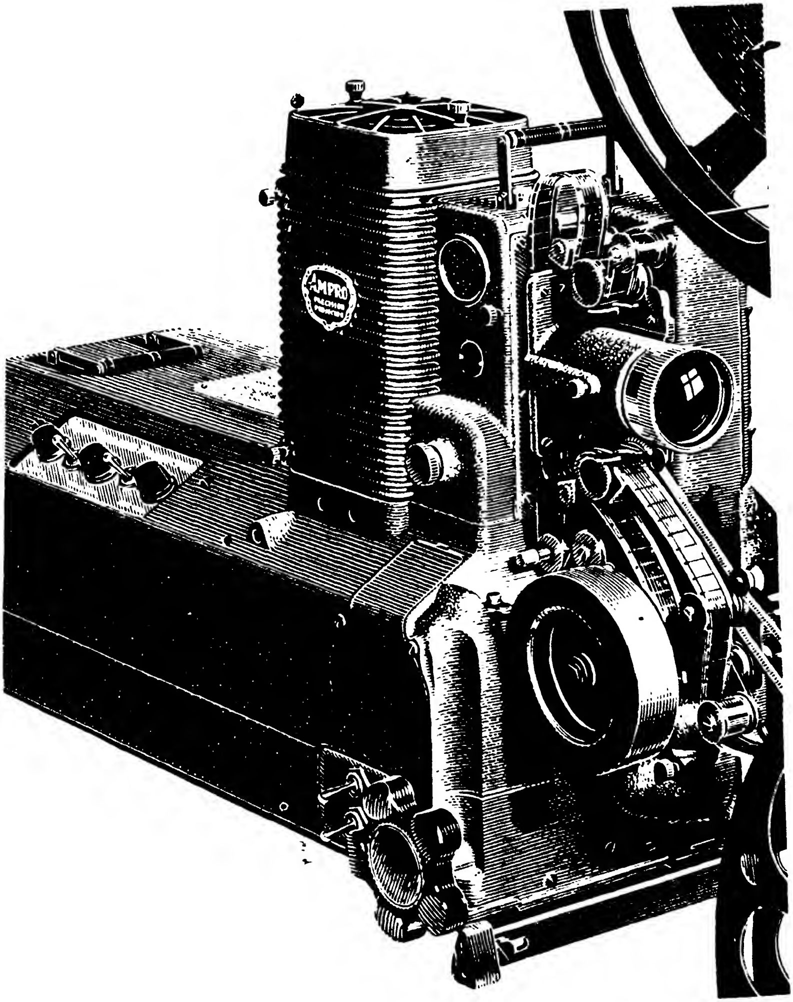
Turn on the Starting Switch (10, Plate A-20) and the Lamp Switch (11, Plate A-20). Focus picture on the screen by using the Projection Lens (12, Plate A-20). If the picture is not in "frame" (Portions of two picture frames being seen on screen), turn the Framing Knob (49, Plate A-20) to correctly frame the picture.

To adjust the sound output, turn the Projector Volume Control Knob (14, Plate A-20) until suitable sound level is obtained. Adjust Tone Control Knob (31, Plate A-20) until proper sound quality is obtained. After picture has been projected, first turn off Projector Lamp Switch (11, Plate A-20), then turn off Microphone Volume Control and then the starting switch.

AMPRO CARBON ARC PROJECTOR

To set up this equipment, remove projector and lamphouse from case and assemble projector and stand on telescoping legs. Install self for amplifier and adjust the projector stand and legs for correct height. Connect the midget plug on the "Y" type line cord to the power socket in back of the projector. Connect the power cord to the power supply. Fold reel arms into proper position and start the projector to make

sure that it is operating properly. Shut off the projector and connect up the rectifier in accordance with the diagram. Close the dowser on the lamp house and start the lamp. Start the projector and open the dow-



ser. Adjust the projector for proper height so that projected light will be properly positioned on screen. Shut off the projector and arc lamp. Always take care

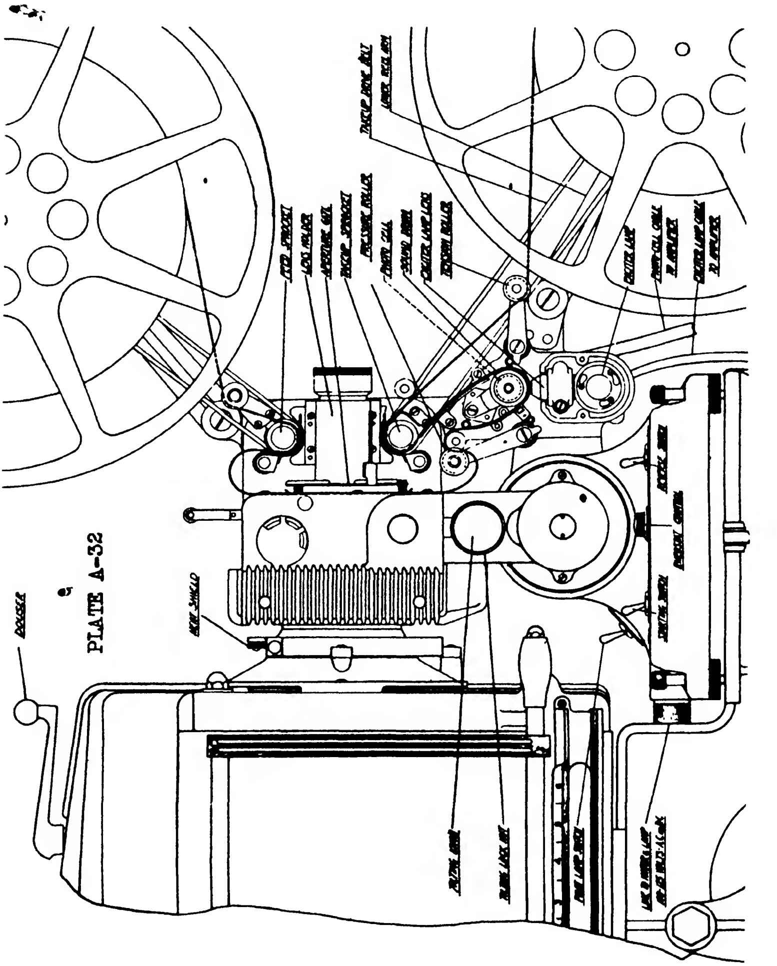


PLATE A-32

to close the dowser before stopping the projector.

Now place the amplifier on the shelf beneath the projector stand. Connect the midget female plug on the "Y" power cord to the line socket located on the left-hand end of the amplifier, provided the power supply is 60 cycle A. C. Plug one end of the speaker cord into the speaker jack on the left hand receptacle. Connect the other end of the speaker cord to the speaker. If additional speakers are used, plug one end of short speaker cord into the other jack on the speaker to which the amplifier is connected, and connect the other end of the cord to the additional speaker. Up to eight speakers may be used by connecting additional cords between the speakers. At least two speakers should be used. The speakers should be so placed that best sound output is secured and so that the sound has the illusion of coming from the screen.

SPEAKER MATCHING PLUG

On the left hand receptacle is a six prong female receptacle, from the center of which protrudes a small jumper wire with pin connector. If one speaker is used, insert the pin connector in the receptacle marked for one speaker, 16 ohms. If two speakers are used, insert the plug in the receptacle marked for two speakers, 8 ohms; if three are used, insert the plug in the receptacle marked for three speakers, 5 ohms; and so on.

Connect the monitor speaker, if used, to the jack marked "monitor" on the left hand receptacle.

STARTING THE AMPLIFIERS

Rotate the line switch from "OFF" to "HI" and observe the A. C. voltmeter. Leave switch in this position if the meter reads green. If the meter reads below green, turn the switch to "Normal" (next position). If line voltage is low, the meter will still read below green, so turn the switch to "low." Always set the switch so that the meter reads green. Below green is O. K., but above in the red is very dangerous to the life of the tubes.

Connect the exciter lamp cable to the jack on the left of the amplifier. Then connect the photocell cable to either of the receptacles marked "photocell" on the right hand end of the amplifier.

OPERATION OF EQUIPMENT

Turn on the amplifier switch. Adjust the photocell voltage control until a low hiss is heard in the speaker. This adjustment should be made with the controls marked "Channel 1" and "Channel 2" turned to mid-position. The photocell control is located on the right hand end of the amplifier.

The output meter is connected to the output transformer so that it reads the output correctly when the proper impedance speakers are connected. If the impedance switch is connected incorrectly, the meter will be in error. The output meter is Calibrated arbitrarily in view of the varying situations that exist. The operator should make a test and determine the correct meter setting with the speakers used, the programs usually offered, and the local conditions affecting the acoustics of the auditorium. The output meter reads beyond the undistorted output of the amplifier because often a peak power in the neighborhood of 100 watts is required. With the average type of program, the output meter reads 100 when the amplifier output is 100 watts. Various wave shapes of sound will affect the peak power.

The average power represents watts of power as impressed on your ear. If the desired volume in any particular set up requires the meter to swing up to 50 it is an indication that more speakers are required. If the meter swings up to 100, at least four speakers are required. If the volume is still not loud enough, add additional speakers or more sensitive speakers. The meter is unusually fast acting and active but of course any operator must have considerable practice in order to "ride" volume. When once the correct volume is established, the meter will be most useful and convenient in maintaining it constant.

R. C. A. FANTASOUND SYSTEM

The RCA Fantasound system is really three complete sound systems of a special type combined into one. In presenting the picture two films are run simultaneously, one a standard film with picture and soundtrack, and the other a special 35 mm. sound film with four double-width soundtracks. Three of the soundtracks are standard program tracks carrying music and dialogue, while the fourth is a special control track that will be described in detail subsequently.

The sound film is run through a special multi-track soundhead, which is synchronized with the associated picture projector by means of a Selsyn drive. Provisions have been made to run the two special soundheads in conjunction with any two of the three available picture projectors.

The signal outputs of the four soundtracks pass through a special relay fader system and are amplified by four separate pre-amplifiers. Each of the three amplifiers handling program material feeds a special variable gain amplifier, which in turn feeds a 30-watt driver amplifier. Each drive amplifier feeds two 60-watt power amplifiers connected in parallel, giving a rated output of 120 watts per channel. While these amplifiers are rated at 120 watts, it was found in tests that they actually delivered 200 watts with less than 2% distortion. This makes a total of 600 watts of undistorted power output available for the three main channels.

To handle this tremendous power output three huge de luxe loudspeaker systems are located on the left center, and right side of the stage. Each setup has 4 large folded type low-frequency baffles with 8 low-frequency speaker units, and one large cellular high-fre-

quency horn with special throat and 4 high-frequency speaker units. This gives a total of 36 de luxe speaker units on the stage!

Two additional 50-watt power amplifiers are connected to the driver amplifier on the two side channels through suitable attenuator pads. Each of these amplifiers drives 22 small cabinet-type loudspeakers that are distributed about the auditorium.

The fourth, or control, track recording on the sound film automatically controls the gain of the three variable gain amplifiers in the three main amplifier channels and hence automatically controls the loudness of the reproduction from each of the speaker set-ups. The control track is a recording of three different artificial oscillator tones of varying intensities superimposed on one another. The three tones are amplified by the control track pre-amplifier, then further by the amplifiers in the control track, and finally passed into filters which separate the tones from one another and feed each to the proper variable-gain amplifier.

The gain, or "volume-control setting," of the variable-gain amplifier is determined by the strength of the control tone that reaches it. Hence, by increasing the intensity of one control tone with respect to the others on the soundtrack it is possible to make the gain of one amplifier channel greater than the others and the reproduction from one set of speakers louder than the others.

With this brief description of the function of the Fantasound system let us see how it is possible to get more realistic reproduction than can be obtained with a standard system.

A recording of a symphony orchestra reproduced by a standard system does not have all of the tone color and spirit of the original because the volume or dynamic range has to be *compressed* when the recording is made. Physical limitations of the recording system make compression necessary. The smallest modulation that it is practical to record on a soundtrack is limited

by the film background noise. The limit is reached when the ratio of signal to noise becomes so small that noise becomes perceptible in reproduction.

The largest modulation that can be recorded is 100% when the peaks of the recorded wave extend to the very edges of the soundtrack area. The dynamic or volume range between these two limits is approximately 35 decibels; whereas the actual range of a symphony orchestra is approximately 70 decibels. Thus a means must be provided for restoring the 35 decibels that were lost because it was necessary to compress the range in the recording process.

If it were possible for the projectionist to twirl the volume control knob rapidly enough according to a complete set of cues, he could continually boost or reduce the gain by just the right amount at the right time and thus compensate for the compression introduced during recording. However, because of the innumerable changes required, this is too tough an assignment, hence some sort of automatic means must be used. In the Fantasound system this means is the control track and the variable-gain amplifiers which are inserted in each amplifier channel.

The control track was recorded after the final re-recordings of the program tracks were made in approximately the following manner. The output of an oscillator generating a single artificial tone, let us say 250 cycles, was connected both to the input of the control track recorder and to a variable-gain amplifier in a standard reproducing system. As each recording was played through the reproducing system, a musician controlled the output of the oscillator in accordance with a set of cues that had been carefully worked out. As he varied the level of the oscillator signal to the variable gain amplifier, he restored the full dynamic range of the original music to the reproduction. At the same time all of the minute variations in the level of the control tone were being permanently recorded on the control track to be used from then on to automatically control the volume in reproduction.

A control track was recorded in the aforementioned way for each of the three program tracks, but a different frequency control tone was used for each. The three resulting control records were then combined into one and recorded on the sound film along with the three program tracks.

The extra volume range obtained by this method is about 40 decibels or about 10,000 times that of a conventional system. This extra amplification would not be of much value if the power amplifiers and loudspeakers were not capable of handling the tremendous peak powers this amplification requires. As described in the foregoing text, a total of 700 watts of audio power with neglible distortion and 80 loudspeaker units were provided to handle these peaks!

Having the loudness of the reproduction as great as that of the original is in itself not enough to give a feeling of realism. In fact, it has been proved that when music is reproduced over a single channel, the audience becomes uneasy if the music is made very much louder than normal. This has been found to be due to the fact that theater loudspeakers are necessarily very directional and, therefore, all the sound appears to come from a single point. This does not mean that directional characteristics of theater loudspeakers are necessarily undesirable. On the contrary, this characteristic adds greatly to the illusion on dialogue, and helps to obtain acceptable intelligibility under adverse acoustic conditions.

An orchestra, however, is generally spread out over all of the stage. Many of the sound waves they create are non-directional. It is not surprising, therefore, that the reproduction of such an orchestra over a single channel system with highly directional speakers leaves something lacking.

In the Fantasound system three huge main speaker systems occupy a width greater than that of the sound screen, so that the sound comes from the whole stage and not just one section. In addition to the stage speakers, small cabinet-type speakers are installed along both

sides of the auditorium and across the rear. Normally, these are operating at so low a level that the audience does not realize they are there; however, they add materially to the illusion.

When directional stage speakers are used even though they are spread, most of the sound energy is directed down into the audience, and much less sound energy strikes the walls than if a live orchestra were playing. If a person were seated in an auditorium listening to a live orchestra, much of the sound reaching his ear would have been reflected from the walls about him so he gets the illusion of sound coming from all sides. The additional auditorium speakers help simulate this condition in the reproduction of Fantasia and places the audience in the midst of the music.

One further effect which adds realism to the sound reproduction is that of "acoustic perspective", or the process of making sound move about the screen in accordance with the action taking place. This can easily be accomplished with the Fantasound system, since three separate channels are available each with its own signal source and loudspeaker system. Disney uses acoustic perspective to obtain very striking effects in this picture.

The tremendous amount of research and study involved in developing this unique sound system and the experience gained in its installation and test have opened up a complete new field in sound-on-film reproduction. It is felt that many of the advantages of this system can soon be made available to all theaters in a somewhat simplified form.

It is noteworthy that, aside from the special multitrack soundheads and variable gain amplifiers, all components of this special sound system are standard sound reproducing items that are being sold with current theater sound equipment. This means that if the application of these special recording methods becomes more general, the sound equipments now installed in theaters will not become obsolete but instead may be used as the main part of a new enlarged system.

Because Disney wanted to produce unusual effects with acoustic perspective, making the sound appear to move about the auditorium and issue from many sources instead of only one as in a standard sound reproducing system, it was necessary to expand the Fantasound system into three complete sound systems, with three separate amplifier channels and three stage speaker setups located on the right, center and left of the stage, respectively.

To supply each of these three channels with separate sound sources, it was necessary to use three program soundtracks instead of the usual one. Then to automatically adjust the volume level of each channel to get greater volume range and more realistic reproduction, it was necessary to use a fourth track, which is known as the control track.

Obviously, there was not room on a standard film for four soundtracks, so a special sound film carrying the three program tracks and the control track was recorded on standard 35 mm. stock. In reproduction, the sound film and the picture film are run simultaneously, the former in a special multi-track soundhead and the latter in a standard picture projector.

The control track has three separate tones recorded on it, superimposed on one another. The tones used are 250, 630 and 1600 cycles. As will be shown later, the intensity of each of these tones determines the loudness of the reproduction from one of the three amplifier channels. Each of the soundtracks on this film is twice normal width, so that it is possible to record signals on them that are twice as loud as the loudest signal that could be recorded on a standard soundtrack.

The accepted volume range of a standard variable area soundtrack is 35 decibels. This means that if the weakest signal recorded on the sound track is made 35 decibels lower in level than the loudest signal that can be recorded within the limits of the soundtrack, the inherent film noise due to graininess, scratches, etc., becomes noticeable in comparison to the weakest signal.

By doubling the width of the soundtrack the loudest signal may be made 6 decibels louder, so that the total usable range then becomes 41 decibels with the same signal-to-noise ratio that is found in standard recordings.

Disney however, has chosen to limit the range that he actually recorded on the film to only 25 decibels, so that the weakest signal recorded on the "Fantasia" soundtracks is a full 16 decibels higher in level than the weakest signals found on standard soundtracks. This means that the signal at all times is many times greater than the film background noise and hence the reproduction is unusually quiet. It was possible to restrict the recorded range in this manner because the control track was available to supply the necessary volume range to the music once again.

The range of control on the variable gain amplifiers is so great that it is possible to expand the 25 decibel volume range recorded on the film to the full 70 decibel volume range of a large symphony orchestra.

To reproduce signals from four soundtracks simultaneously, RCA engineers had to develop a special multi-track soundhead. This soundhead has its own mounting pedestal and a set of upper and lower magazines. It is driven by a three-phase Selsyn drive motor which keeps it always in exact synchronism with the picture projector which is also driven by a Selsyn drive motor from the same Selsyn generator.

A double, reversible exciter lamp socket is provided carrying one active and one spare exciter lamp. If an exciter lamp should burn out, it is necessary only to remove the socket, reverse it, and re-insert it to put a new lamp in position. A special optical system forms the light from a signal exciter lamp into a uniform scanning beam that is one mil. wide and long enough to scan all four tracks.

A standard rotary stabilizer could not be used because the entire film has to be scanned and the solid sound take-off drum would not allow light to pass through. Hence a special aperture was developed to

permit this type of scanning. A magnetically-driven drum located immediately below the aperture drives the film past the scanning point at a very uniform speed. The magnetic drive is identical to the one that has been used on all RCA Film Recorders for many years.

The meter shown in illustration indicates the strength of the current that is being fed to the magnetizing coils on the magnetic drive. The knob immediately below the meter adjusts a rheostat which controls this magnetizing current.

A pair of rollers ahead of the scanning aperture and another after the magnetically-driven drum maintain film loops which filter out any irregularities which may be imparted to the motion of the film by the feed and hold-back sprockets.

After the scanning light passes through the film at the aperture, it passes on to four photocells mounted in a front photo-cell compartment. Each photocell is connected to its own photocell transformer which matches the high impedance of the cell to a low-impedance line which couples the soundhead to the amplifier system.

The complex control signal (combination of three tones) generated in the control track photocell is amplified and built up to a high level by a pre-amplifier, voltage amplifier, and a power amplifier. This high-level signal is then fed to each of the three main channel amplifier racks. A 250-cycle band-pass filter on Rack 1 accepts the 250-cycle portion of the complex control tone and rejects the other two tones. A 630-cycle band-pass filter on Rack 2 and a 1600-cycle band-pass filter on Rack 3 accept 630 and 1600 cycles, respectively, rejecting the undesired components. In this way, the complex control tone is separated into its individual parts and one tone goes to each rack.

After coming through the band-pass filter each control tone is fed to a tone rectifier which rectifies the A.C. tone producing a D.C. voltage. The value of this D.C. voltage is at all times proportional to the strength of the control tone, becoming higher as the control tone

gets stronger.

The variable D.C. voltage is then applied to the grid circuit of the first amplifier stage of the variable gain amplifier as a bias voltage. The first stage of the amplifier consists of a balanced pair of RCA 6K7 tubes in a push-pull circuit. The RCA 6K7 is a remote cut-off, super control pentode tube so constructed that the gain of the tube may be varied over wide limits by changing the bias voltage.

Two ordinary amplifier stages follow this variable gain stage to further amplify the signal before passing it on to the power amplifiers. Controls are available on this amplifier to change the expansion characteristics so that varying degrees of volume changes can be obtained for a given change in control signal. By this arrangement the equipment can be adjusted to give any overall volume range that the size and acoustics of the theater will permit.

By the proper combination of these two new pieces of sound reproducing equipment with standard Photophone amplifiers, speakers, and power supply units, a very versatile system has been created which now brings unprecedented sound reproduction to theater audiences. It is expected that the future will bring even more unusual effects and more realistic reproduction.

EXAMINATION QUESTIONS

The answers to these questions will be found in the text pages of this book. A duplicate set of these questions with several hundreds of others, with the answer directly under each question will be found in QUESTIONS AND ANSWERS ON SOUND MOTION PICTURES.

State the troubles to be expected in a Dynamic Speaker and how they can be overcome.

Give some of the reasons for distorted sound output from speakers.

Who discovered the principle of the electro-dynamic drive, how is this used in sound picture work? What are the advantages of the electro-dynamic speaker over the moving iron type speaker?

What is a condenser loud-speaker?

What is a dynamic cone?

State what causes "hum" in speakers and how this can be eliminated.

What effect will the placing of the projection room above the center of the screen have on the projected picture?

How may an alternating current be produced from an ordinary direct current motor or dynamo?

Why will a short circuited field coil run cool while a short circuited armature coil becomes very warm?

How is it possible to locate an open circuited field in a motor?

What is it necessary to change about a motor in order to make it operate on a circuit of double its voltage?

State the different types of alternating current motors.

Why does the speed of a motor increase as the field coils get warm?

Why does the speed of a series motor tend to become excessively high?

Is it possible to reverse the rotation of a motor, if so, how?

How is the speed of constant current motor governed?

Why is the sparking less in a dynamo and greater in a motor when the brushes are rocked forward in the direction of rotation?

What parts of a dynamo are liable to be short circuited?

How would you set the brushes of a dynamo so that it would spark less with a load than without a load?

What is a thoriated filament?

What are the various elements in a vacuum tube?

If tubes are in series and one burned out, how could you find the dead tube?

What is the difference between frosted, sprayed, dipped and natural colored lamps, and in what colors are each available from the manufacturer?

What amperage should be drawn by a 600 watt lamp used in projection?

What three factors determine the quality of lamps?

In ordering lamps, what four essentials must be specified?

Give a short description of a photo-voltaic cell.

Will a DC 700-A motor control cabinet operate with all tubes removed?

What is Selenium?

What would you do in case of an insufficient plate current reading?

Name three types of cells now in use.

What portion of the film should the light through the "slit" illuminate?

Give a short description of a photo-conductive cell.

What is the reason a filament rheostat will cause noise?

What constants in a vacuum tube are governed by the condition of the filament?

What would cause an unsteady and fluctuating plate current in a vacuum tube?

What are the dimensions of the light beam when it reaches the sound track?

What is a thermionic vacuum tube?

What is a "glow lamp"?

What is a "vacuum"?

What is a "discharge tube"?

What are actinic rays?

What is an "audion"?

What is an "audio frequency push-pull amplifier," how is it connected in the circuit and how does it work?

Can light energy like electrical energy be stored?

What is a filament rheostat?

Where would you look for the cause of distorted sound output, taking it for granted that the input is not distorted?

Where would you look for trouble in the dynamic speaker should it suddenly go dead?

What advantage, if any, has the Variable Area Method of sound recording over the Variable Density Method?

What is a filter as used in camera work and in the reproduction of sound?

What is a disc condenser?

State what is meant by a "diaphragm" as used in camera work and in telephone receiver.

What causes sprocket noise, how does this sound?

What is an AC pick-up?

What is a screen grid tube?

What is meant by the term "cycle"?

What is a "jack"?

What is a volume indicator?

What is a condenser (a) as used in electricity; (b) as used in optics?

What is a variable density sound track?

What causes "sprocket hum"?

What is meant by the term "damping"?

Is it true that a storage battery "stores" electricity?

What is meant by "background noise"?

Is it possible for the projector to run with varying speeds?

What would be the result should the projection speed vary?

What happens to the high frequency sounds when the projector or disc turntable is overspeeded?

State what care should be given the optical pick-up each day.

Do light waves and sound waves travel in straight lines?

Name the two methods used for recording sound-on-film.

What is meant by "volume level" in projection?

What is the meaning of the term synchronous?

What is intermediate frequency?

What is the amplitude of waves?

What is amplitude, pitch and quality of sound?

Do amplification and volume mean the same thing?

State what is meant by "reverberation time."

What is an electrical condenser?

State the characteristics of sound.

What is meant by an amplifier "motorboating"? How did this trouble get this name?

We talk of the pitch of a sound; what is pitch?

What is an overtone?

What is an audio frequency transformer coupled amplifier?

What is the duty of a bypass condenser?

Give a description of the actino-electric effect.

State what care should be given the optical pick-up each day?

State what care should be taken of selenium cells.

State the theory of operation of a vacuum tube.

What would a high plate current reading indicate?

Are tubes sometimes noisy?

What harm does too high filament current do to the life of the tube?

What does a rectifying tube do?

How can tubes be tested?

What is a grid; a, in a vacuum tube, b, in a storage battery?

What is meant by high vacuum?

The action of a colliding electron upon an atom is termed "ionization by collision," explain how this works, and if it is an advantage in a vacuum tube.

What are photo-electrons?

Describe in detail how a rectifier tube is constructed and how it operates.

What is the "amplification factor" of a three electrode tube?

What is the theory of the detector action of a vacuum tube?

What is grid bias?

State the theory of the vacuum tube amplifier?

What is the input circuit of a vacuum tube?

What is meant by the plate of a vacuum tube?

What is a hard tube?

What are electrons?

What is a neon lamp?

What is a tube rectifier?

Where are rectifier tubes used in sound motion picture circuits?

What is the rated average life of Mazda lamps used in motion picture projection work?

What is filament current?

How should Mazda lamps designed for motion picture pro jection be installed?

Suppose on looking over your motor you found that there were several ridges on the commutator, where would you look for the cause?

In changing from a lens of small diameter to one of larger diameter or from a lens of large diameter to one of smaller diameter, what change might be necessary in the shutter blades?

What is meant by the equivalent focus of a projection lens?

What will be the effect on the screen of a badly pitted and dirty condenser?

What is an achromatic lens?

What is meant by the focal point of a lens?

What is barrel distortion?

What is meant by the front and back combinations of an objective lens?

Should projection lenses be held tightly in their mounts, should condenser lenses be mounted tightly?

Define a condensing lens.

What is reflection of light?

What is the object of a lens?

What is the optical axis?

What is refraction of light?

What is chromatic aberration?

What is spherical aberration?

What factors decide the size of lens required?

What is meant by the back focal length of a lens?

Why should the inside of the lens barrel be painted black?

What comprises the optical system of a projector?

What is used to cement lenses together?

Describe an objective lens.

Give your definition of motion pictures.

Why are flicker shutters made with two or three blades

What is a bridging amplifier?

What is a "mixer" as used in sound recording?

What is a compensator?

What is a condenser microphone?

What is a commutator ripple?

Describe the motors used in driving RCA projectors.

State what a mechanical filter is used for.

What is meant by term "bloop"?

What is meant by a keystone effect?

What is effective aperture?

Of what use are the condensers?

What determines the size of the condenser lens?

The photo-electric cell has a silver lining, and has one wire connected to this lining. Is this wire positive or negative?

What causes a flow of current in the photo-electric cell?

What is the ring-shaped wire in the center of a photo-electric cell?

State in what ways the photo-electric cell resembles the three electrode vacuum tube.

What would be the effect should the photo-electric cell not receive a sufficient potential?

Were the projector to vibrate and these vibrations passed on to the photo-electric cell, would this have any effect on reproduction of sound?

What might happen if the photo-electric cell becomes turned in its holder so that half the window or opening in the cell is covered?

Describe in its simplest form the construction of a photo-electric cell.

The negative wire from the photo-electric cell is connected where?

Which wire from the photo-electric cell connects with the grid of the first tube?

In the RCA Photophone system what coupling is used between the cell and amplifier?

How is the W.E. photo-electric cell amplifier coupled, and how many stages has it?

In the case of insufficient polarizing voltage supplied to an electric cell what would happen?

What will happen if the photo-electric cell is not mounted tightly?

Give a description of a gas type photo-cell.

What is amplification?

What is meant by Low Frequency?

What is a variable area sound track?

What is "remote control"? Give an instance where this is used.

What is "audio frequency amplifier"?

What is meant by the "additive process" in color photography?

Describe an adjustable condenser?

What is a magnetic field?

What is the use of an electrical pick-up?

What is a recording amplifier and what is it used for?

What is plate control?

What amperage is needed for Mazda lamps used in motion picture projection work?

Which end of the lens goes towards the screen?

What is meant by a keystone effect?

What is effective aperture?

Of what use are the condensers?

What determines the size of the condenser lens?

When the picture size is increased, without other changes, will there be apparent loss of light on the screen?

What would cause a travel ghost on screen?

Describe a spherical mirror.

What is a relative aperture?

What is meant by the absorption of light?

Describe a stereopticon.

What is working distance, when referring to an objective lens?

What is meant by the working distance of a lens?

Why are the curved surfaces of the condenser lenses placed next each other?

Describe what is meant by condenser lenses, as used in motion picture work.

What is "halation"?

Define footage marks.

What portion of the film should the light through the slit illuminate?

Describe what is meant by "variable density" and "variable area" method of recording sound on film.

What type of film must be used to replace film removed due to breaking, patching, etc.?

On disc film what is the start mark?

Which of the lines, the dark ones or the light ones, make the actual sound?

What effect on reproduction will a poorly made sound track splice have?

What is film buckling?

What causes surface noise on film?

Give a short description of a photo-electric cell.

State the three known types of light sensitive cells.

What is a light-valve as used in sound recording?

INDEX

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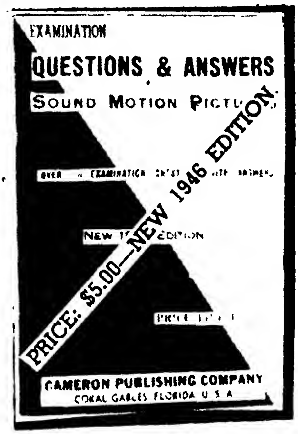

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